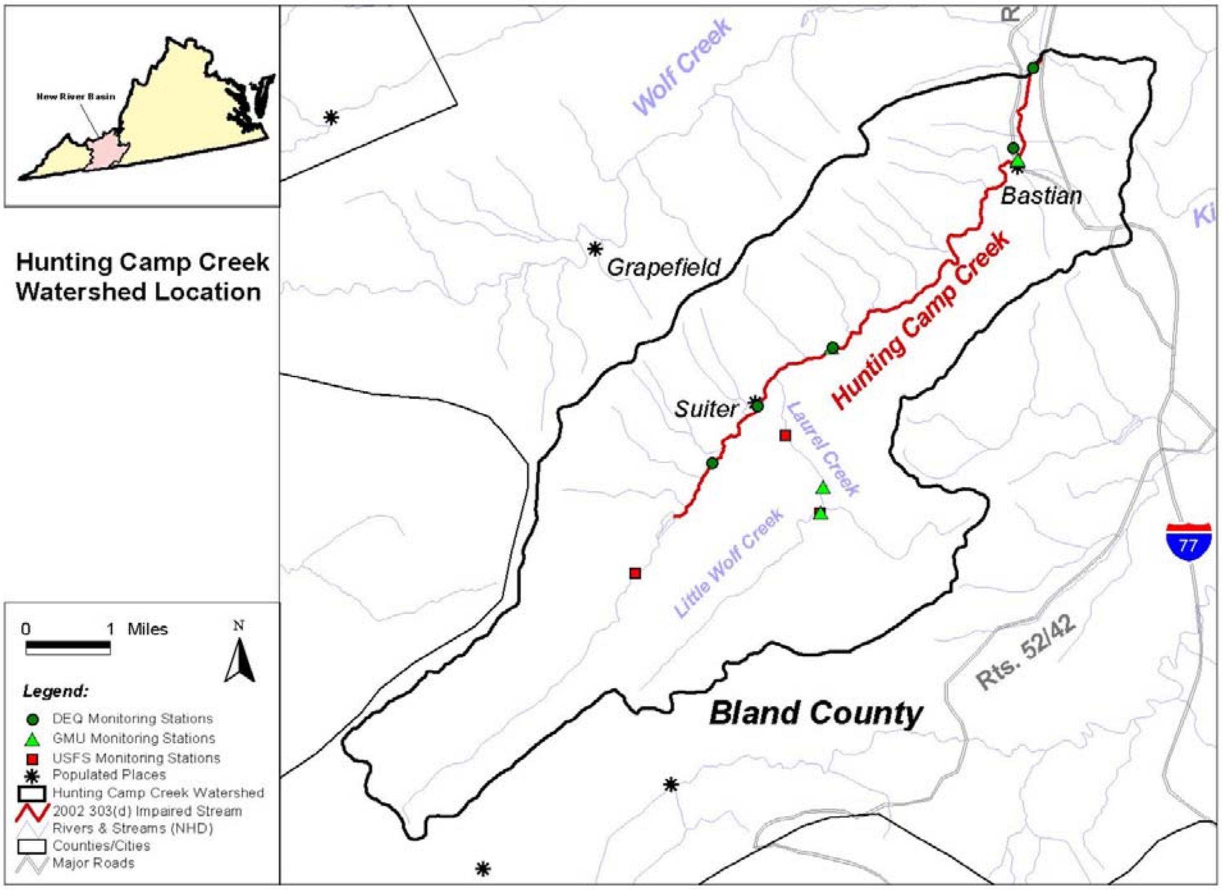
Total Maximum Daily Load (TMDL) Development for Hunting Camp Creek

Aquatic Life Use (Benthic) and E. coli (Bacteria) Impairments



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SECTION 1

INTRODUCTION

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA 1991).

1.1.2 Impairment Listing

Hunting Camp Creek was listed as impaired on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the State's Water Quality Standards for fecal coliform bacteria and violations of the General Standard (Benthics) (VADEQ 1998 & 2002a). The impaired segment is 8.45 miles in length and begins at the impoundment on Hunting Camp Creek above the community of Suiter and continues downstream to the confluence with Wolf Creek. Hunting Camp Creek was initially listed as impaired for violations of the General Standard (Benthics) in 1998. The upstream limit of the original impaired segment was the confluence with Laurel Creek. Hunting Camp Creek was also listed as impaired for fecal coliform bacteria in 2002 and the segment was extended an additional 1.21 miles based on a landuse survey conducted during the assessment period.

1.1.3 Watershed Location

The Hunting Camp Creek watershed (Virginia WBID: VAS-N31R) is located in the New River Basin (HUC: 05050002) in Bland County, Virginia. The headwaters begin in the Jefferson National Forest and the stream flows in a northeasterly direction through forest and pasture land to its confluence with Wolf Creek. Laurel Creek is the largest tributary to Hunting Camp Creek. The communities of Bastian and Suiter are located in this 20,603 acre watershed (Figure 1.1).

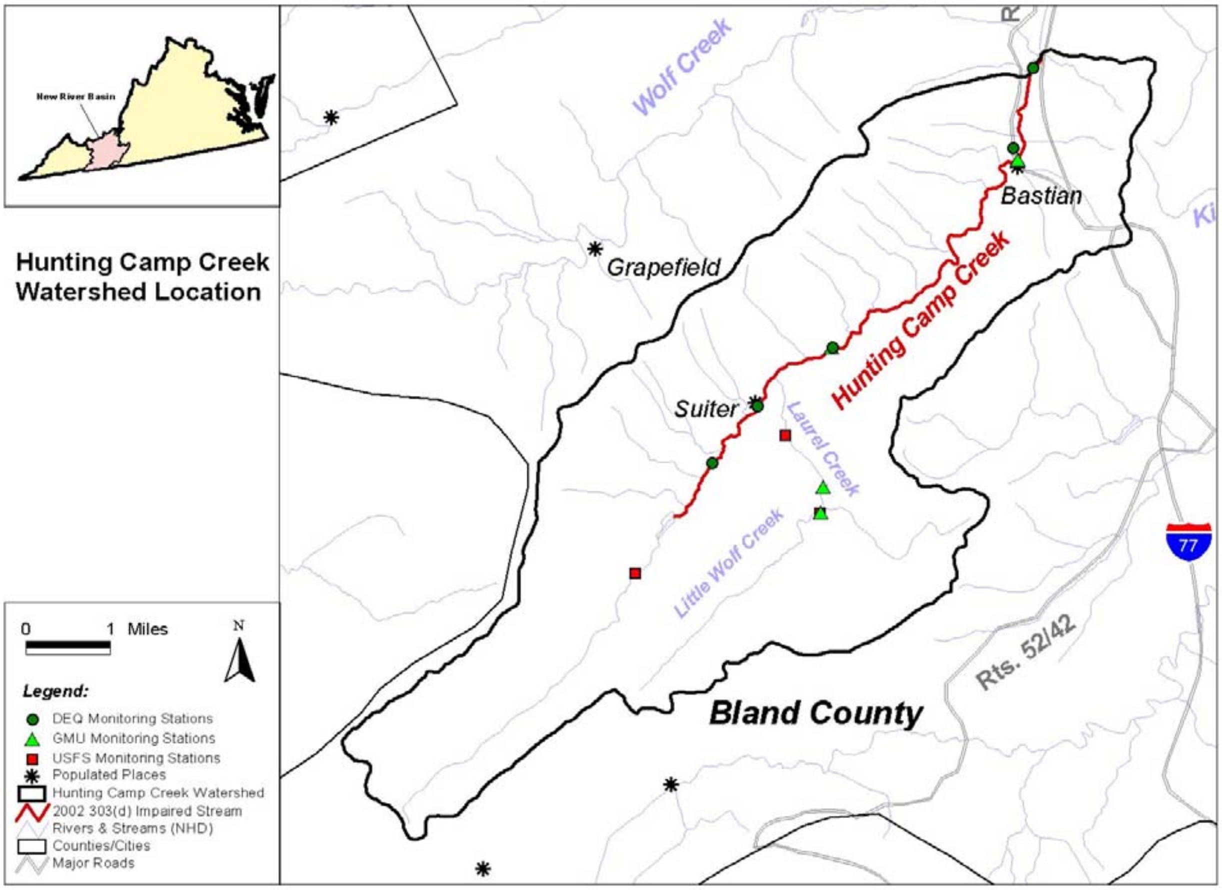

Figure 1.1 Location of the Hunting Camp Creek watershed

1.2 Designated Uses and Applicable Water Quality Standards

According to Virginia's Water Quality Standards (9 VAC 25-260-5), the term "Water quality standards" *means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§ 62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC § 1251 et seq.).*

1.2.1 Designation of Uses (9 VAC 25-260-10)

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

Hunting Camp Creek does not support the recreation (swimming) designated use due to violations of the Bacteria Criteria. The stream also partially supports the aquatic life designated use due to violations of the General Criteria (Benthic).

1.2.2 Water Quality Standards

Bacteria (9 VAC 25-260-170)

Hunting Camp Creek was listed as impaired on Virginia's 2002 303(d) list for non-compliance with the following fecal coliform bacteria criteria:

A. *General Requirements: In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.*

Virginia's Water Quality Standards were amended to include new criteria for fecal coliform bacteria, *E. coli*, and *enterococci*. Standards were adopted for *E. coli* and *enterococci* because of the higher correlation between *E. coli* and *enterococci* concentrations and gastrointestinal illness. These new criteria became effective on January 15, 2003. Fecal coliform bacteria and *E. coli* criteria apply to Hunting Camp Creek, which is a freshwater stream. Bacteria concentrations are expressed as the number of colony forming units per 100ml of water (cfu/100ml):

A. *In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:*

1. *Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.*

2. *E. coli and enterococci bacteria per 100 ml of water shall not exceed the following:*

	Geometric Mean[1]	*Single Sample Maximum[2]*
Freshwater[3]		
E. coli	*126*	*235*
Saltwater and Transition Zone[3]		
enterococci	*35*	*104*

[1] For two or more samples taken during any calendar month.
[2] No single sample maximum for enterococci and E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.

General Criteria (9 VAC 25-260-20)

A. *All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*

   Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled.

1.3 Water Quality Assessment and TMDL Endpoint Selection

1.3.1 Bacteria Assessment

Hunting Camp Creek was listed as impaired for fecal coliform bacteria on Virginia's 303(d) list based on monitoring conducted by VADEQ. Elevated levels of fecal coliform bacteria were recorded at two water quality monitoring stations on Hunting Camp Creek. VADEQ began monitoring for *E. coli* in 2000 in anticipation of the change in indicator species. Elevated levels of *E. coli* have also been recorded on Hunting Camp Creek. As a result, Hunting Camp Creek does not currently support the Recreation (swimming) designated use.

TMDL development requires the identification of a numeric endpoint that will allow for the attainment of designated uses and water quality criteria. The new fecal coliform bacteria criteria specified in 9 VAC 25-260-170 shall not apply after a minimum of 12 samples for *E. coli* have been collected or after June 30, 2008, whichever comes first. As a result, the applicable TMDL endpoint is compliance with the recently adopted *E. coli* criteria. Virginia's Water Quality Standards specify a maximum *E. coli* bacteria concentration of 235 cfu/100ml, at any time, and a geometric mean criteria of 126 cfu/100 ml for two or more samples over the calendar month period (9 VAC 25-260-170).

1.3.2 Biomonitoring and Assessment

Direct investigations of biological communities using rapid bioassessment protocols, or other biosurvey techniques, are best used for detecting aquatic life impairments and assessing their relative severity (Plafkin et al. 1989). Biological communities reflect overall ecological integrity; therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act. Biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their aggregate impact. Communities also integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.

Many state water quality agencies use benthic macroinvertebrate community data to assess the biological condition of a waterbody. Virginia uses EPA's Rapid Bioassessment Protocol (RBP II) to determine the status of a stream's benthic macroinvertebrate community. This procedure relies on comparisons of the benthic macroinvertebrate community between a monitoring station and its designated reference site. Measurements of the benthic community, called metrics, are used to identify differences between monitored and reference stations. Metrics used in the RBP II protocol include taxa richness, percent contribution of dominant family, and other measurements that provide information on the abundance of pollution tolerant versus pollution intolerant organisms. Biomonitoring stations are typically sampled in the spring and fall of each year. The biological condition scoring criteria and the bioassessment matrix are discussed in the technical document, *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish* (Plafkin et al. 1989). The RBPII bioassessment scoring matrix is presented in Table 1.1.

Table 1.1 Bioassessment scoring matrix (Plafkin et al. 1989)

% Compare to Reference Score (a)	Biological Condition Category	Attributes
>83%	Non-Impaired	Optimum community structure (composition and dominance).
54 - 79%	Slightly Impaired	Lower species richness due to loss of some intolerant forms.
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms.
<17%	Severely Impaired	Few species present. Dominant by one or two taxa. Only tolerant organisms present.
(a) Percentage values obtained that are intermediate to the above ranges require subjective judgment as to the correct placement.		

Virginia 305(b)/303(d) guidance states that support of the aquatic life beneficial use is determined by the assessment of conventional pollutants (dissolved oxygen, pH, and temperature); toxic pollutants in the water column, fish tissue and sediments; and biological evaluation of benthic community data (VADEQ 2002b). Benthic community assessments are, therefore, used to determine compliance with the General Criteria section of Virginia's Water

Quality Standards (9 VAC 25-260-20). In general, the stream reach that a biomonitoring station represents is classified as impaired if the RBP ranking is either moderately or severely impaired.

Biomonitoring data collected by VADEQ on Hunting Camp Creek indicate an impairment of the benthic macroinvertebrate community. According to the 2002 303(d) Impaired Waters Fact Sheet, erosion and sedimentation was observed along the stream as it flows through predominately pasture land. This portion of the stream corridor is characterized by denuded banks with evident streambank erosion. Urban development around Bastian is also believed to contribute to the benthic impairment.

SECTION 2

WATERSHED CHARACTERIZATION AND MONITORING SUMMARY

2.1 Background

2.1.1 TMDL Definition and Regulatory Information

The Hunting Camp Creek watershed (Virginia WBID: VAS-N31R) is located in the New River Basin (HUC: 05050002) in Bland County, Virginia. The headwaters begin in the Jefferson National Forest and the stream flows in a northeasterly direction through forest and pasture land to its confluence with Wolf Creek. Laurel Creek is the largest tributary to Hunting Camp Creek. The communities of Bastian and Suiter are located in this 20,603 acre watershed.

2.1.2 Geology

The Hunting Camp Creek watershed is located in Valley and Ridge physiographic province. The Valley and Ridge physiographic province is characterized by elongate parallel ridges and valleys that are underlain by folded Paleozoic sedimentary rock. This topography is the result of the continuous differential weathering of linear belts of rocks that have been repeatedly exposed and covered by folding and faulting. Cambrian clastic sediments of the western Blue Ridge are overlain by carbonates that made up the Great American Bank. Today these carbonates (up to 3.5 km in thickness) are exposed in the Great Valley. Well-developed karst topography is characteristic of the Great Valley and many caverns are located on the subsurface.

2.1.3 Soils

Soils data were obtained from the State Soil Geographic (STATSGO) database which includes general soils data and map unit delineations for the United States. GIS coverages provide accurate locations for the soil map units (MUIDs) at a scale of 1:250,000 (NRCS 1994). A map unit is composed of several soil series having similar properties. The Hunting Camp Creek watershed includes three different soil map units: VA001-center/north ridge, VA003-Laurel Creek south ridge, and VA004-along the mainstem channel. VA001 is the predominant soil type in the watershed (86%). The following soil series descriptions are based on NRCS Official Soil Descriptions (1998-2002).

STATSGO Soil Type VA001 is composed of the Berks and Weikert series. The Berks series accounts for most of the map unit and consists of moderately deep, well drained soils formed in residuum weathered from shale, siltstone and fine grained sandstone on rounded and dissected uplands. Permeability is moderate or moderately rapid and slopes range from 0 to 80 percent.

STATSGO Soil Type VA003 is composed of the Frederick and Carbo series. The Frederick series accounts for most of the map unit. This series consists of very deep, well drained soils formed in residuum derived mainly from dolomitic limestone with interbeds of sandstone, siltstone, and shale. These soils are on nearly level to very steep uplands and slopes range from 0 to 66 percent. Permeability is moderate.

STATSGO Soil Type VA004 is composed of the Moomaw, Jefferson, and Alonzville series. The Moomaw series accounts for most of the map unit and consists of very deep, moderately well drained, slowly or moderately slowly permeable soils on stream terraces. These soils have a fragipan and are formed in alluvium derived from acid sandstone, quartzites, and shales. Slopes range from 0 to 30 percent.

2.1.4 Climate

The area's climate is typical of other regions in the Valley and Ridge province. High mountain ridges form the watershed boundary for Hunting Camp Creek and influence the local weather in this watershed. Weather data for the Hunting Camp Creek watershed can be generally characterized using the Staffordsville 3 N meteorological station (NCDC #448022), which is located approximately 24 miles northeast of the watershed (period of record: 9/1/51 – 3/31/04). The growing season lasts from May 4 through October 5 in a typical year (SERCC 2003). Average annual precipitation is 38.37 inches with July having the highest average precipitation (3.94 inches). Average annual snowfall is 23.1 inches, most of which occurs in January and February. The average annual maximum and minimum daily temperature is 64.9^{o}F and 41.4^{o}F, respectively. The highest monthly temperatures are recorded in July (83.6^{o}F - avg. maximum) and the lowest temperatures are recorded in January (22.9^{o}F - avg. minimum).

2.1.5 Land Use

General land use/land cover data for the Hunting Camp Creek watershed were extracted from the Multi-Resolution Land Characterization (MRLC) database for the state of Virginia (USEPA 1992) and is shown in Figure 2.1. This database was derived from satellite imagery taken during the early 1990s and is the most current detailed land use data available. Land uses in the Hunting Camp Creek watershed include various urban, agricultural, and forest categories (Table 2.1 and Figure 2.1). Approximately 93% of the watershed is forested with 6% used for agricultural purposes. Residential and commercial development account for less than 1% of the watershed.

Table 2.1 MRLC and consolidated land uses in the Hunting Camp Creek watershed

MRLC Land Use	Area (acres)	Percent	Consolidated Land Use	Area (acres)	Percent
Woody Wetlands	6	0.03%	Forest	19,136	92.9%
Emergent Herbaceous Wetlands	34	0.16%			
Deciduous Forest	12,654	61.41%			
Evergreen Forest	2,376	11.53%			
Mixed Forest	4,066	19.73%			
Open Water	22	0.11%	Water	22	0.1%
Pasture/Hay	1,081	5.25%	Pasture/Hay	1,081	5.2%
Row Crops	134	0.65%	Cropland	134	0.7%
Transitional (barren lands, strip mining, etc.)	83	0.40%	Transitional	83	0.4%
Low Intensity Residential	53	0.26%	Urban	149	0.7%
High Intensity Commercial/Industrial/Transportation	96	0.46%			

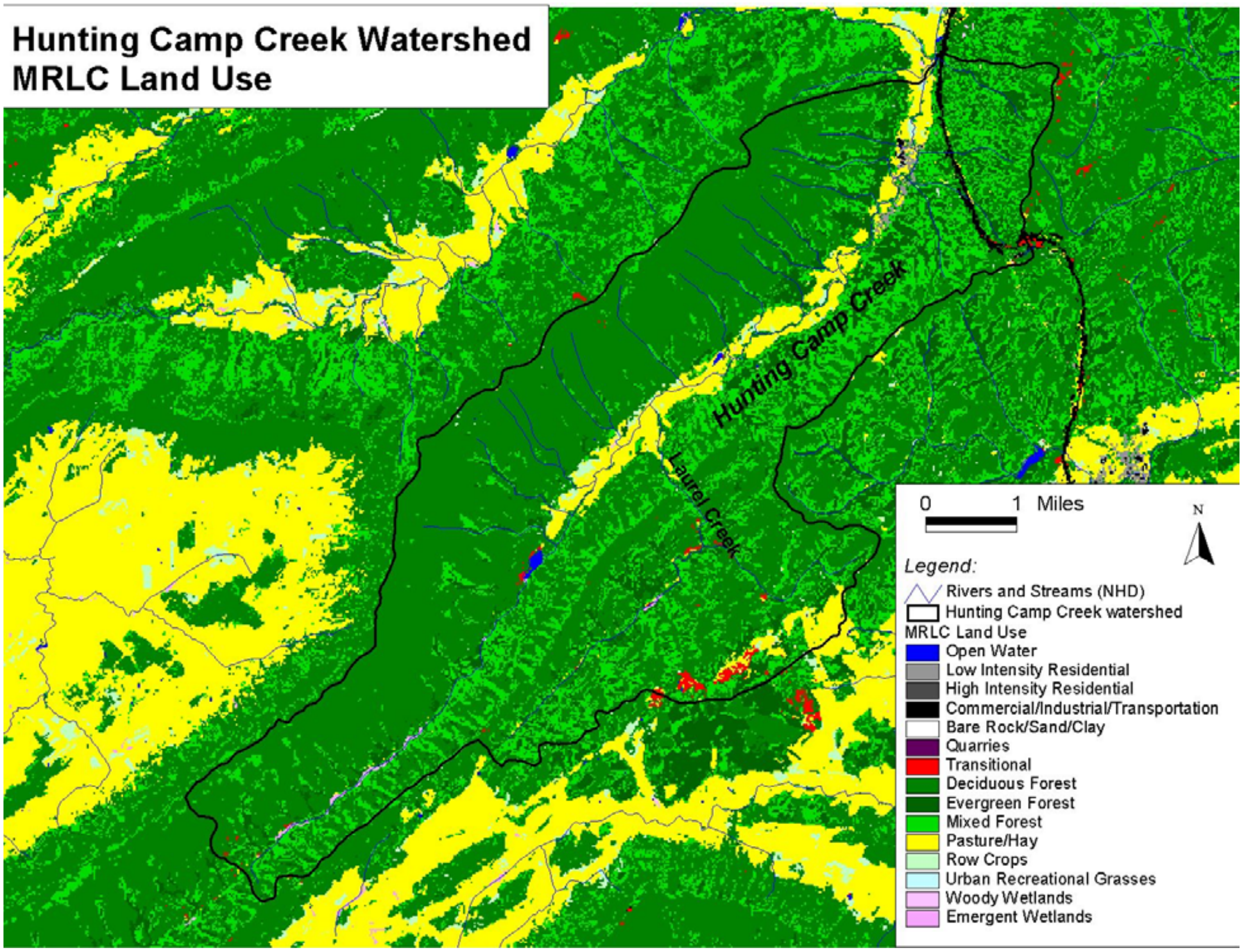

Figure 2.1 MRLC land use in the Hunting Camp Creek watershed

2.1.6 Ecoregion

The Hunting Camp Creek watershed is located in the Central Appalachian Ridges and Valleys ecoregion - Level III 67 (Woods et al. 1999). This ecoregion is a northeast-southwest trending, relatively low-lying, but diverse ecoregion, sandwiched between generally higher, more rugged mountainous regions with greater forest cover. As a result of extreme folding and faulting events, the region's roughly parallel ridges and valleys have a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, sandstone, chert, mudstone, and marble. Springs and caves are relatively numerous. Present-day forests cover about 50% of the region. The ecoregion has a diversity of aquatic habitats and species of fish.

At a finer scale, the Hunting Camp Creek watershed is located in the Southern Sandstone Ridges subecoregion - Level IV classification 67h respectively (Woods et al. 1999). The Southern Sandstone Ridges subecoregion is composed of high, steep, forested ridges with narrow crests. The ridge-forming strata are composed of folded, interbedded Paleozoic sandstone and conglomerate. Other less resistant rocks, such as shale and siltstone, form the side slopes. Today, extensive forest covers the region. Crestal elevations range from about 2,300 feet to 3,450 feet and local relief ranges from approximately 500 to 1,500 feet.

2.2 Stream Characterization

Hunting Camp Creek flows northwest from its headwaters to its confluence with Wolf Creek in Bland County, Virginia. Hunting Camp Creek flows predominantly thorough forest and pasture/hay lands in this narrow stream valley with high mountain ridges. A shale/sandstone geology is dominant with exposed bedrock in several areas along the stream. The mainstem in the lower portion of the watershed flows through pasture land and is utilized for livestock watering in some areas and other agricultural production activities. The stream corridor is characterized by denuded stream banks and evidence of streambank erosion with little riparian vegetation in agricultural areas, primarily due to livestock grazing.

2.3 Water Quality and Biomonitoring Summary

2.3.1 Monitoring Stations

Data collected on Hunting Camp Creek and tributaries include DEQ Ambient Water Quality Monitoring (AWQM), special study, sediment, and biomonitoring data; GMU water quality data; U.S. Forest Service (USFS) water quality and biomonitoring data. Monitoring station locations and a detailed assessment of the data collected is presented in Section 5. The primary water quality monitoring stations on Hunting Camp Creek are stations 9-HCC001.40 (located at the Rt. 52/21 bridge crossing in Bastian) and 9-HCC005.57 (located at the Rt. 646 bridge crossing upstream). Station 9-HCC001.40 is also the primary VADEQ biomonitoring station in the watershed. Other stations in the watershed have been sampled over the past few years for water quality and biomonitoring.

2.3.2 Fecal Coliform Bacteria and *E. coli* Data

Data collected by VADEQ from 2/23/00 through 8/30/04 were compared to the new instantaneous and geometric mean criteria for fecal coliform bacteria and *E. coli* (Table 2.2). Bacteria Source Tracking (BST) data collected at these stations from 7/21/03 through 6/21/04 were included in this analysis. The results of the BST study are presented in Section 2.3.3.

Table 2.2 Bacteria monitoring summary

Station	Date	Sample Type1	Count	Min-Max	Instantaneous Criteria FC: 400 cfu EC: 235 cfu (% Violations)
9-HCC001.40	2/23/00 – 6/21/04	FC	26	20-4,000	42
	7/21/03 – 8/30/04	EC	13	2-800	31
9-HCC005.57	7/21/03 – 6/21/04	FC	12	1-600	17
	7/21/03 – 7/21/04	EC	14	1-780	29

[1] Sample type: FC = Fecal Coliform Bacteria, EC = *E. coli*

2.3.3 Bacteria Source Tracking (BST)

VADEQ collected BST data at stations 9-HCC001.40 and 9-HCC005.57 from 7/21/03 through 6/21/04 (12 monthly samples) to help identify the predominant sources of bacteria in the watershed (Table 2.3). Fecal coliform bacteria and *E. coli* concentrations were measured and the Antibiotic Resistance Analysis (ARA) methodology was used to determine the likely sources of bacteria in each sample. This methodology provides information on the presence or absence of human, pet, livestock, and wildlife sources in the watershed. No information was provided for upstream areas of the watershed.

Table 2.3 BST results (average of 12 monthly samples)

Station	Wildlife (%)	Human (%)	Livestock (%)	Pets (%)
9-HCC001.40	45	34	6	15
9-HCC005.57	31	36	20	13

2.3.4 Biomonitoring Data

VADEQ currently uses EPA's Rapid Bioassessment Protocol (RBP II method) to determine the impairment status of monitored streams based on comparisons to reference streams. Stations 9-HCC001.40 and 9-HCC007.83 were sampled on several occasions from 1994 through 2004. USFS conducted biomonitoring at three stations in the watershed (Jefferson National Forest lands) in 1994: station 7021 (Hunting Camp Creek), station 7004 (Laurel Creek), and station 7026 (Little Wolf Creek). The impairment listing was based on biomonitoring data collected at VADEQ station 9-HCC001.40. Bioassessment information is provided in Section 5.

SECTION 3

SOURCE ASSESSMENT – BACTERIA

Point and nonpoint sources of bacteria in the Hunting Camp Creek watershed were considered in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources including, agricultural and land use information, water quality monitoring and point source data, GIS coverages, past TMDL studies, literature sources, and other information. Procedures and assumptions used in estimating bacteria loads are described in the following sections.

3.1 Assessment of Nonpoint Sources

Agricultural and urban sources of bacteria are referenced in the 2002 303(d) Fact Sheet for Hunting Camp Creek. Nonpoint sources of bacteria can include failing septic systems and leaking sewer lines, straight pipes, livestock (including manure application loads), wildlife, and domestic pets. The Bastian WWTP (waste water treatment plant) went online in the summer of 2003. Many houses in the watershed are now connected to the sewage collection system, alleviating the need for a septic tank. The representation of the following sources in the model is discussed in Section 4.

3.1.1 Septic Systems and Straight Pipes

Residential septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. Fecal coliform bacteria naturally die-off as the effluent percolates through the soil to the groundwater. These systems effectively remove fecal coliform bacteria when properly installed and maintained.

A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff into surface waters. Failing septic systems can deliver high bacteria loads to surface waters, depending on the proximity of the discharge to a stream and the timing of rainfall events. Septic system failures typically occur in older systems that are not adequately maintained with periodic sewage pump-outs.

An estimated 145 people live in houses with a septic system or other means of sewage disposal (e.g., straight pipe) in the Hunting Camp Creek watershed, as determined using the following methods. Initial septic and straight pipe estimates were determined using U.S. Census block-group data for Year 2000 (Census 2000). These estimates were not used in model development because the Bastian WWTP went online in the summer of 2003, which resulted in the connection of many houses in the watershed to the sewage collection system. Considering the new Bastian

WWTP, the number of houses in the watershed were identified based on the location of structures as depicted on USGS 7.5 minute topo maps (24K Digital Raster Graphics) and an estimated 90% hook-up rate was used to determine the number of remaining septic systems and houses with straight pipes. The number of houses estimated to be connected to the Bastian WWTP (hook-up rate) was based on information provided by the local Virginia Department of Health office (E. Moretz, pers. comm. 2004). The population served by the remaining septic systems and straight pipes in the watershed was determined using a 2.17 persons/house multiplier, based on Bland County census data for Year 2000.

The number of failing septic systems was estimated using a failure rate of 20% based on information provided by the Virginia Department of Health and the average age of the septic systems in the watershed. A fecal coliform bacteria concentration of 105 cfu/100mL and a septic system waste flow of 70 gallons/person/day was used to estimate the contribution from failing septic systems to surface waters (Metcalf and Eddy, Inc. 1991). In some cases, human waste is directly deposited into surface waters from houses without septic systems. These "straight pipes" and other illicit discharges are illegal under Virginia regulations. Houses with straight pipes are typically older structures that are located in close proximity to a stream. The population served by straight pipes was assumed to be 1% of the septic population in the watershed. Houses considered to have a normal functioning septic system were assumed to have a negligible contribution of fecal coliform bacteria to surface waters.

3.1.2 Livestock

Animal population estimates for beef cattle and horses were based on information provided by local stakeholders at the first Hunting Camp Creek TMDL public meeting and discussions with Big Walker Soil and Water Conservation District staff (K. Johnson, pers. comm.. 2004). Population estimates are provided in Table 3.1. Other livestock animals, such as dairy cattle, are either not found in the Hunting Camp Creek watershed or the population sizes are negligible.

Table 3.1 Livestock population estimates

Livestock Species	Hunting Camp Creek Population
Beef Cattle	56
Horses	15

Bacteria produced by livestock can be deposited on the land, directly deposited in the stream (as is common when grazing animals have stream access), manually applied to cropland and other agricultural lands as fertilizer, or contributed to surface waters through illicit discharges from animal confinement areas. Bacteria deposited on the land, either directly or through manure application, are available for washoff into surface waters during rainfall events. There are no known illicit discharges of animal waste in the watershed.

Grazing animals, such as beef cattle, typically spend portions of the day confined to loafing lots, grazing on pasture lands, and watering in nearby streams. The percentage of time spent in each area effects the relative contribution of bacteria loads to the stream. The amount of time beef cattle spend in or near streams primarily depends on time of year and the availability of stream access and off-stream watering facilities. Estimates of the amount of time cattle spend in these different areas were based on information provided by local stakeholders at the first Hunting Camp Creek TMDL public meeting and watershed modeling results (Table 3.2). Beef cattle in the watershed are not confined, therefore manure from these animals is not typically collected and applied to agricultural lands. Horse estimates were also based on stakeholder comments and past TMDL studies. Horses were assumed to spend the majority of each day in pasture (75% of the day in pasture during March - November, 35% in December - February). Horses are stabled during winter months and colder periods.

Table 3.2 Beef cattle - daily hours spent grazing and in streams

Month	Grazing (hours)	Stream Access (hours)
January	24	0
February	21.4	2.6
March	21.1	2.9
April	20.4	3.6
May	20.4	3.6
June	20.4	3.6
July	20.4	3.6
August	20.4	3.6
September	20.4	3.6
October	20.4	3.6
November	21.6	2.4
December	24	0

Collected horse manure was applied to cropland and pasture in the Hunting Camp Creek watershed based on manure application information obtained from other regional TMDL studies. The majority of the manure collected was applied to cropland (75%) in spring and fall months. A small percentage of the manure collected was applied to pastureland areas in the winter and summer months. The application of collected manure follows the schedule listed in Table 3.3. The manure is used to fertilize corn and other primary crops in the spring and winter wheat in the fall. Tillage allows for the incorporation of fecal coliform bacteria that is applied to the soil surface. Based on field observations of cropland in the watershed and past TMDL studies, it was assumed that 25% of the manure that was applied was incorporated into the soil, resulting in 75% of the fecal coliform bacteria load being available for washoff.

Table 3.3 Horse manure application – fraction applied each month (of the annual total)

Month	Fraction of Manure Applied
January	0
February	0.05
March	0.25
April	0.2
May	0.05
June	0.05
July	0.05
August	0.05
September	0.1
October	0.1
November	0.1
December	0

Fecal coliform bacteria production rates used for livestock species in the Hunting Camp Creek watershed are listed in Table 3.4. A variety of sources were consulted to determine the appropriate daily fecal coliform bacteria production value for each species, including other valley TMDL studies and literature sources.

Table 3.4 Livestock fecal coliform bacteria production rates

Livestock Species	Daily Production (cfu/animal/day)	Primary Sources
Beef cattle	4.46×10^{10}	ASAE 1998, USGS 2002
Horses	5.15×10^{10}	ASAE 1998, USGS 2002

3.1.3 Wildlife

Wildlife species in the watershed were identified through consultation with the Virginia Department of Game and Inland Fisheries (VDGIF). The predominant species include ducks, geese, deer, beaver, raccoon, and muskrat. The population of each wildlife species was estimated using the population density per square mile of habitat area and the total area of suitable habitat in the watershed (Table 3.5). Habitat areas were determined using GIS and the watershed land use coverage (MRLC). The density and habitat assumptions used to estimate the population of each wildlife species were updated based on information provided by state and local VDGIF personnel. Population estimates and the defined habitat of each species in the Hunting Camp Creek watershed are listed in Table 3.6. Percent time spent in streams was adjusted based on recent TMDL studies and watershed model calibration data.

Table 3.5 Wildlife population density by land use (# animals per square mile of habitat)

Land Use	Ducks		Geese		Deer	Beaver	Raccoon	Muskrat
	Summer	Winter	Summer	Winter				
Cropland	30	40	50	70	0	5	2.5	320
Pasture/Hay	30	40	50	70	35	5	2.5	160
Forest	10	20	0	0	35	10	5	160
Built-Up (Urban)	30	40	50	70	0	5	2.5	320

Table 3.6 Wildlife habitat descriptions, population estimates, and percent of time spent in streams

Wildlife Species	Habitat Description	# of Animals	% in Streams
Ducks	100 meter buffer around perennial streams for all land uses	36 in summer 58 in winter	2.5%
Geese	100 meter buffer around perennial streams for Pasture/Hay, Cropland, and Built-Up	34 in summer 48 in winter	2.5
Deer	25 deer/mi^2 for Pasture and Forest	506 year-round	1
Beaver	20 meter buffer around perennial streams for all land uses	4 year-round	50
Raccoon	0.5 mile buffer around perennial streams for all land uses	80 year-round	1
Muskrat	20 meter buffer around perennial streams for all land uses	80 year-round	2.5

As with grazing livestock, wildlife deposit on the land and directly to surface waters. The percentage of fecal coliform bacteria directly deposited to surface waters was estimated based on the habitat of each species. The remaining fecal coliform load was applied to the upland landuses, according to the total area of each landuse within established habitat areas. The typical fecal coliform density for each wildlife species was used to calculate fecal coliform bacteria loads (Table 3.7).

Table 3.7 Fecal coliform bacteria production rates for wildlife species

Wildlife Species	Daily Production (cfu/animal/day)	Primary Sources
Ducks	7.35×10^9	ASAE 1998, USGS 2002
Geese	7.99×10^8	USGS 2002
Deer	3.47×10^8	VADEQ 2001
Beaver	2.0×10^5	VADEQ 2000
Raccoon	5.0×10^9	VADEQ 2001
Muskrat	2.5×10^7	VADEQ 2001

3.1.4 Domestic Pets

Domestic pets were also considered in source assessment and watershed modeling. The bacteria contribution from domestic pets was represented by the waste deposited by dogs. The contribution from other pets was considered negligible. Housing estimates were used to determine the number of dogs in the watershed. Based on the assumption of one dog per two households, the number of dogs in the Hunting Camp Creek watershed was estimated to be approximately 148. The fecal coliform concentration in dog waste is 1.85 x 109 cfu/100mL (Mara and Oragui 1981).

3.2 Assessment of Point Sources

Point sources, such as municipal sewage treatment plants, can contribute fecal coliform bacteria loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ. There are no point sources that discharge to Hunting Camp Creek or its tributaries. The Bastian WWTP discharges to Wolf Creek downstream, therefore, the contribution from this point source does not impact bacteria levels in Hunting Camp Creek.

SECTION 4

WATERSHED MODELING – BACTERIA

Establishing the relationship between the in-stream water quality targets and source loadings is a critical component of TMDL development. It allows for evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. The objective of this section is to present the approach taken to develop the linkage between sources and in-stream response for the development of bacteria TMDLs for Hunting Camp Creek.

4.1 Modeling Framework Selection

Selection of the appropriate approach or modeling technique required consideration of the following:

• Expression of water quality criteria
• Dominant processes
• Source Integration
• Scale of analysis
• Efficient TMDL scenario evaluation

The applicable criteria for bacteria are presented in Section 1. Numeric criteria require evaluation of magnitude, frequency, and duration. *E. coli* water quality criteria are presented as both an instantaneous maximum standard (235 cfu/100ml) and a geometric mean standard (126 cfu/100ml, minimum of two samples collected within a calendar month period). The approach or modeling technique must permit representation of in-stream concentrations under a variety of flow conditions in order to evaluate critical periods for comparison to these criteria.

The appropriate approach must also consider the dominant processes regarding pollutant loadings and in-stream fate. For the Hunting Camp Creek watershed, primary sources contributing to bacteria impairments include an array of nonpoint or diffuse sources as well as discrete direct inputs to the stream either by permitted point source discharges or animal direct deposition to the streams. Loading processes for nonpoint sources or land-based activities are typically rainfall-driven and thus relate to surface runoff and subsurface discharge to a stream.

Key in-stream factors that must be considered include routing of flow, dilution, transport, and fate (decay or transformation) of bacteria. In the Hunting Camp Creek watershed, the primary physical process affecting the transport of bacteria is the die-off rate.

Scale of analysis and waterbody type must also be considered in the selection of the overall approach. The approach should have the capability to evaluate watersheds at multiple scales, and be able to adequately represent the spatial distribution of sources and the delivery processes whereby bacteria are delivered throughout the stream network.

Based on the considerations described above, analysis of the monitoring data, review of the literature, characterization of the bacteria sources, the need to represent source controls to individual sources, and previous modeling experience, the Loading Simulation Program C++ (LSPC) was selected to represent the source-response linkage in the Hunting Camp Creek watershed. LSPC, the primary watershed modeling system for the EPA TMDL Toolbox, is currently maintained by the EPA Office of Research and Development in Athens, GA (http://www.epa.gov/athens/wwqtsc).

Note that the model predicts fecal coliform bacteria concentrations. *E. coli* bacteria concentrations are estimated using the VADEQ fecal coliform bacteria/*E. coli* translator in order to compare the results to the instantaneous and geometric mean criteria for *E. coli* and develop TMDLs (VADEQ 2003).

4.1.1 Loading Simulation Program C++ (LSPC) Overview

LSPC is a watershed modeling system that includes streamlined Hydrologic Simulation Program Fortran (HSPF) algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model. A key data management feature of this system is that it uses a Microsoft Access database to manage model data and weather text files for driving the simulation. The system also contains a module to assist in TMDL calculation and source allocations. For each model run, it automatically generates comprehensive text-file output by subwatershed for all land-layers, reaches, and simulated modules, which can be expressed on hourly or daily intervals. Output from LSPC has been linked to other model applications such as EFDC, WASP, and CE-QUAL-W2. LSPC has no inherent limitations in terms of modeling size or model operations. The Microsoft Visual C++ programming architecture allows for seamless integration with modern-day, widely available software such as Microsoft Access and Excel.

LSPC was designed to facilitate data management for large-scale or complex watershed modeling applications. The model has been successfully used to model watershed systems composed of over 1,000 subwatersheds at a National Hydrography Dataset (NHD) stream-segment scale. The system is also tailored for source representation and TMDL calculation. The LSPC GIS interface, which is compatible with ArcView shapefiles, acts as the control center for launching watershed model scenarios. This stand-alone interface easily communicates with both shapefiles and an underlying Microsoft Access database, but does not directly rely on either of these main programs. Therefore, once a watershed application is created, it is easily transferable to users who may not have ArcView or MS Access installed on their computers.

Selected HSPF modules were re-coded in C++ and included in the LSPC model. LSPC's algorithms are identical to those in HSPF. Table 4.1 presents the modules from HSPF that are incorporated in LSPC. The user may refer to the Hydrologic Simulation Program FORTRAN User's Manual for a more detailed discussion of simulated processes and model parameters (Bicknell et al. 1996).

Table 4.1 HSPF modules available and supported in the LSPC watershed model

Simulation Type	HSPF Module	HSPF Module Description
Land Based Processes	PWATER	Water budget for pervious land
	IWATER	Water budget for impervious land
	SNOW	Incorporates snow fall and melt into water budget
	SEDMNT	Production and removal of sediment
	PWTGAS	Est. water temperature, dissolved gas concentrations
	IQUAL	Simple relationships with solids and water yield
	PQUAL	Simple relationships with sediment and water yield
In-stream Processes	HYDR ADCALC	Hydraulic behavior, pollutant transport
	CONS	Conservative constituents
	HTRCH	Heat exchange, water temperature
	SEDTRN	Behavior of inorganic sediment
	GQUAL	Generalized quality constituent

Meteorological Data Processing

Weather conditions are the driving force for watershed hydrology processes. For the simulation options selected for the Hunting Camp Creek watershed model, the required parameters include hourly precipitation, hourly potential evapotranspiration, hourly air temperature, hourly wind speed, hourly solar radiation, hourly dew point temperature, and hourly cloud cover. Precipitation, air temperature, wind speed, and cloud cover are measured, while potential evapotranspiration and solar radiation are empirically computed using temperature and gage latitude and cloud cover respectively. Table 4.2 summarizes the weather data that were collected for the Hunting Camp Creek watershed model. These data were obtained from the listed National Climatic Data Center (NCDC) meteorological stations.

Table 4.2 NCDC meteorological datasets compiled for the Hunting Camp Creek watershed model

Station ID	Timestep	Data Type	Station Name	Start Date	End Date	Elevation (ft)
WV5284	Hourly	Precipitation	Lindside	7/1/1957	12/31/2002	1985
VA9215	Hourly	Precipitation	Wise 3 E	11/1/1955	12/26/2002	2549
VA9060	Hourly	Precipitation	White Gate	8/1/1948	10/31/1993	1850
TN1094	Hourly	Precipitation	Bristol AP	9/1/1948	12/31/2002	1500
VA8022	Hourly	Precipitation	Staffordsville 3 ENE	12/1/1993	12/25/2002	1950
03859	Hourly	Precipitation	Mercer Bluefield	1/1/2003	9/30/2004	2891
03872	Hourly	Air Temperature, Wind Speed, Dew Point Temperature, Cloudcover	Beckley WSO AP	5/15/1963	12/31/2002	2504
03859	Hourly	Air Temperature, Wind Speed, Dew Point Temperature, Cloudcover	Mercer Bluefield	9/1/2000	9/30/2004	2891

There were no NCDC monitoring stations located within the Hunting Camp Creek watershed. The nearest hourly station is Mercer Bluefield (03859), which is approximately 3.1 miles north of the watershed. The nearest daily monitoring stations are Mercer Bluefield (03859) and Beckley SWO AP (03872), which are approximately 3.1 miles and 36.47 miles north of the watershed, respectively.

Hourly air temperatures between 1980 and 2004 were used to compute the potential evapotranspiration time-series. This process is described in greater detail in Section 4.1.2.

Of the six precipitation stations, the Wise 3 E station was the most representative of the watershed; however, the period of record ended in 1993. The Staffordville 3 ENE station was used for the period from 1993 to 2002. Missing or deleted intervals in the data were simultaneously patched using hourly data recorded at the other four nearby stations. This entire process is described in greater detail in Section 4.1.3.

4.1.2 Computing Potential Evapotranspiration

Hourly temperature data between 1980 and 2004 from the Beckley WSO AP and Mercer Bluefield stations were used to compute the potential evapotranspiration time-series. The Hamon method (1961) was used to compute evapotranspiration. The Hamon formula states that:

$$PET = CTS \ x \ DYL \ x \ DYL \ x \ VDSAT \qquad \text{Eqn 5.1}$$

where
PET daily potential evapotranspiration (in)
CTS monthly variable coefficient (a value of 0.0055 is suggested)
DYL possible hours of sunshine, in units of 12 hours, computed as a function of latitude and time of year
VDSAT saturated water vapor density (absolute humidity) at the daily mean air temperature (g/cm3)

The formula to compute saturated water vapor density (VDSAT) states that:

$$VDSAT = \frac{216.7 \times VPSAT}{TAVC + 273.3} \quad \text{Eqn 5.2}$$

where
VPSAT saturated vapor pressure at the air temperature
TAVC mean daily temperature computed from daily min and max (Deg C)

The formula for saturation vapor pressure (VPSAT) states that:

$$VPSAT = 6.108 \times \exp\left(\frac{17.26939 \times TAVC}{TAVC + 273.3}\right) \quad \text{Eqn 5.3}$$

4.1.3 Patching Rainfall Data

Unless the percent coverage is 100%, meaning that the weather station is always in operation and is accurately recording data throughout the specified time period, precipitation stations may contain various intervals of accumulated, missing, or deleted data. Missing or deleted intervals are periods over which either the rainfall station malfunctioned or the data records were somehow lost. Accumulated intervals represent cumulative precipitation over several hours, but the exact hourly distribution of the data is unknown.

The normal-ratio method (Dunn & Leopold 1978) was used to repair accumulated, missing, and deleted data intervals based on hourly rainfall patterns at nearby stations where unimpaired data is measured. The normal-ratio method estimates a missing rainfall value using a weighted average from surrounding stations with similar rainfall patterns according to the relationship:

$$P_A = \frac{1}{n}\left(\sum_{i=1}^{n} \frac{N_A}{N_i} P_i\right) \quad \text{Eqn 5.4}$$

where PA is the impaired precipitation value at station A, n is the number of surrounding stations with unimpaired data at the same specific point in time, NA is the long term average precipitation at station A, Ni is the long term average precipitation at nearby station i, and Pi is the observed precipitation at nearby station i. For each impaired data record at station A, n consists of only the surrounding stations with unimpaired data; therefore, for each record, n varies from 1 to the maximum number of surrounding stations (two in this case). When no precipitation is available at the surrounding stations, zero precipitation is assumed at station A. The US Weather Bureau has a long established practice of using the long-term average rainfall as the precipitation normal. Since the normal ratio considers the long-term average rainfall as the weighting factor, this method is adaptable to regions where there is large orthographic variation in precipitation; therefore, elevation differences will not bias the predictive capability of the method. Figure 4.1 shows the 10-year annual rainfall totals at White Gate (1/1/1990-10/31/1993), Lindside (11/1/1993-11/30/1993), and Staffordsville 3 ENE (12/1/1993-12/25/2002). Hourly rainfall measured at Lindside (12/26/2002-12/31/2002) and Mercer Bluefield (1/1/2003-9/30/2004) was used for the remainder of the simulation period 12/26/2002-9/30/2004.

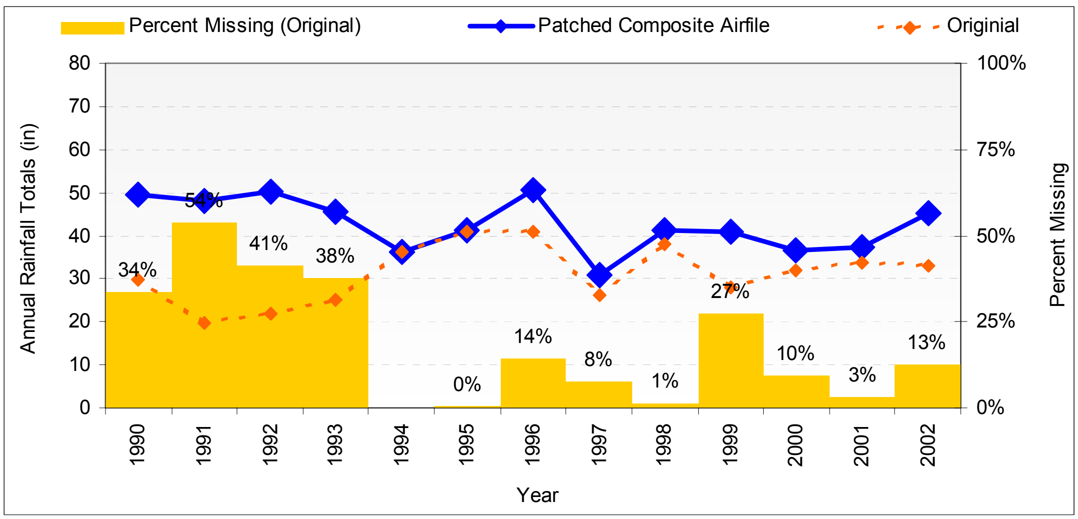

Figure 4.1 Total annual precipitation totals and daily quality at precipitation gages before and after patching

4.2 Model Setup

LSPC was configured for the Hunting Camp Creek watershed to simulate the watershed as a series of hydrologically connected subwatersheds. Configuration of the model involved subdivision of the Hunting Camp Creek watershed into modeling units and continuous simulation of flow and water quality for these units using meteorological, land use, point source loading, and stream data. Continuous, long-term streamflow data are not available for Hunting Camp Creek, therefore, a reference watershed approach was used in order to calibrate hydrologic parameters. Hunting Camp Creek flows into Wolf Creek, which has a long-term USGS streamflow gage located near Narrows, Virginia (USGS 03175500). The LSPC model was developed for the Wolf Creek reference watershed, delineated at the USGS gage, in order to calibrate hydrologic parameters in the model. The model was then configured to analyze bacteria concentrations and contributing sources in the Hunting Camp Creek watershed. This process is further explained in Section 4.6 (Model Calibration Process).

The Wolf Creek watershed, including Hunting Camp Creek, was subdivided into 9 subwatersheds to adequately represent the spatial variation in watershed characteristics, hydrology, and the location of water quality monitoring and streamflow gaging stations (Figure 4.2). The delineation of subwatersheds was based primarily on the location of streams and a topographic analysis of the watershed. The Hunting Camp Creek watershed was delineated at a finer scale (5 subwatersheds) to better represent spatial differences in bacteria sources, hydrologic conditions, and the location of monitoring stations in the watershed.

A continuous simulation period of 14 years and 9 months (1/1/1990-9/30/2004) was used in the hydrologic simulation analysis. This is due to the fact that the period of record for observation data spanned this time period. An important factor driving model simulations is precipitation data. The pattern and intensity of rainfall affects the build-up and wash-off of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream.

Modeled land uses that contribute bacteria loads to the stream include pasture, cropland, urban land (including loads from failing septic systems and pets), and forest. Other sources, such as straight pipes and livestock in streams, were modeled as direct sources in the model. Development of initial loading rates for land uses and direct sources are described in Section 4.3.

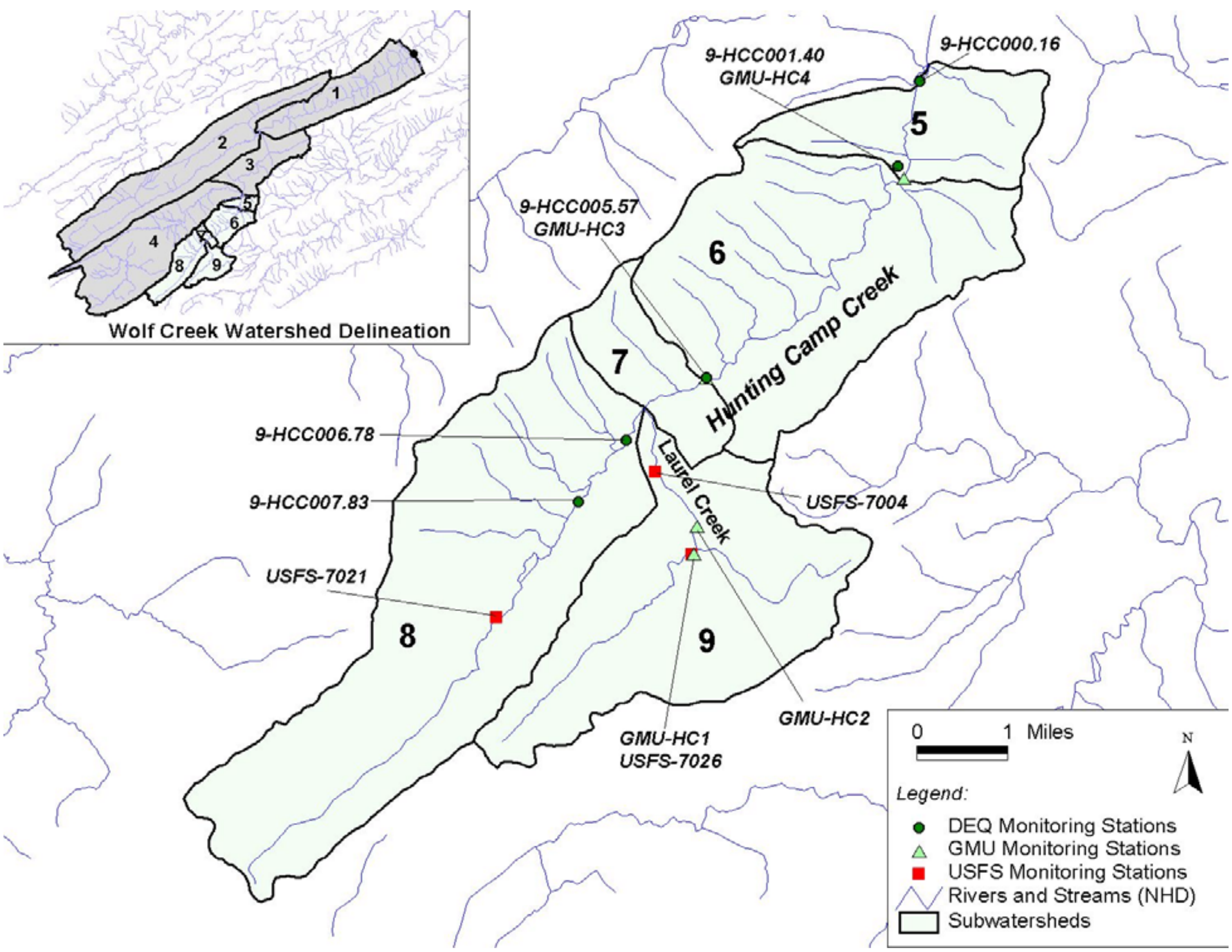

Figure 4.2 Subwatershed delineation (Wolf Creek watershed delineation inset)

4.3 Source Representation

Nonpoint sources of bacteria were represented in the model for Hunting Camp Creek. There are no point sources located in the watershed, therefore, point sources were not included in the model. Land-based nonpoint sources were represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (e.g. animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream.

4.3.1 Failing Septic Systems and Straight Pipes

Septic systems provide the potential to deliver bacteria loads to surface waters due to system failures caused by improper maintenance and/or malfunctions. The number of septic systems in each subwatershed was determined based on housing estimates derived from USGS topographic maps of the watershed and information provided by the local VDH office, as described in Section 3.1.1 (Table 4.3). The construction of the Bastian WWTP in 2003 has considerably reduced the number of active septic systems in the watershed. The number of failing septic systems was estimated using a failure rate of 20% based on information provided by the VDH and previous model development efforts in the region. Failing septic discharges contribute bacteria to the stream through runoff events (included in the urban land load).

In some cases, human waste is directly deposited into surface waters from houses without septic systems. The population served by straight pipes was assumed to be 1% of the septic population in the watershed. These direct discharges are a constant source of bacteria to the receiving stream. Houses considered to have a normal functioning septic system were assumed to have a negligible contribution of fecal bacteria to surface waters.

Table 4.3 Total and failing septic population estimates (by subwatershed)

Hunting Camp Creek subwatershed	Septic Population	Population served by failing septic systems
5	15	3
6	38	8
7	1	0
8	41	8
9	50	10

* 2 people estimated to be using straight pipes

4.3.2 Livestock

Bacteria produced by livestock can be deposited on the land, directly deposited in the stream (as is common when grazing animals have stream access), manually applied to cropland and other agricultural lands as fertilizer, or contributed to surface waters through illicit discharges from animal confinement areas. Bacteria deposited on the land, either directly or through manure application, are available for washoff into surface waters during rainfall events. There are no known illicit discharges of animal waste in the watershed.

Animal population estimates for beef cattle and horses were based on information provided by local stakeholders at the first Hunting Camp Creek TMDL public meeting and discussions with Big Walker Soil and Water Conservation District staff, as described in Section 3.1.2. Bacteria loads directed through each pathway were calculated by multiplying the bacteria density with the amount of waste expected through that pathway.

The population of each livestock species was distributed among subwatersheds based on the total area of pasture in each subwatershed (Table 4.4).

Table 4.4 Livestock population by subwatershed

Hunting Camp Creek subwatershed	Beef Cattle	Horses
5	6	2
6	19	5
7	5	1
8	12	3
9	13	4

Liquid manure from confined animals is applied to cropland and pasture/hayland in the watershed. Beef cattle are not typically confined throughout the year in the Hunting Camp Creek watershed. The only confined animals are horses during colder periods. Application rates vary monthly, with application primarily occurring during the spring and fall, according to the schedule presented in Section 3.1.2. Application of manure results in the accumulation of bacteria on the land surface. Therefore, bacteria accumulation rates are directly influenced by and based on the application rates of manure. To determine bacteria accumulation factors for the model, it was necessary to determine the amount present in manure. The fraction of manure application available for runoff was calculated by subtracting the amount typically incorporated into the soil matrix through tillage and natural processes (assumed 25% soil incorporation).

Beef cattle in streams were represented in the model as direct inputs (e.g. point sources) of bacteria. Using the fecal coliform bacteria production rates for beef cattle, the daily contribution from cattle in streams was calculated and then totaled by subwatershed depending on the population estimates of beef cattle watering in streams in each subwatershed (refer to Section 3.1.2). Bacteria contributions from cattle in streams were represented in the model using the total load delivered to the stream (#/day) and the flow rate at which it is delivered (cfs). The flow rate was determined using the amount of waste produced by beef cattle each day (lb/day) and an assumed density of the manure produced (lb/gal). Cattle in the stream were assumed to discharge at a constant rate.

Grazing animals also contribute bacteria to the land surface, which is available for washoff to surface waters during storm events. Beef cattle were the most abundant grazing animals in the watershed, as shown in Table 4.4. Beef cattle and horses were distributed throughout pasture/hay areas in each subwatershed. Bacteria accumulation rates (#/acre/day) for each of these livestock species were calculated using subwatershed population estimates and the bacteria production rate established for each species.

4.3.3 Wildlife

The population of each wildlife species was estimated using the population density per square mile of habitat and the total area of suitable habitat in each subwatershed (Table 4.5). As with grazing livestock, wildlife deposit manure on the land and directly to surface waters. The habitat and percentage of time each species typically spends in streams was used to determine the proportion of bacteria that was deposited on land versus directly to surface waters. Loads applied to the land (in each subwatershed) were distributed according to the total area of each land use type within the established habitat area of each species.

Table 4.5 Wildlife population by subwatershed

Hunting Camp Creek subwatershed	Ducks		Geese		Deer	Beaver	Raccoon	Muskrat
	Summer	Winter	Summer	Winter				
1	4	5	6	8	42	<1	5	7
2	6	9	7	9	131	1	16	15
3	3	4	5	7	27	<1	4	3
4	15	24	13	19	192	2	32	34
5	9	15	4	6	114	1	23	22

4.3.4 Domestic Pets

Housing estimates were used to determine the number of pets in each Hunting Camp Creek subwatershed. An assumption of one dog per two households was used to calculate the pet population. Bacteria loading was applied to urban (built-up) lands and as direct deposition to the stream in each subwatershed.

4.4 Stream Characteristics

The channel geometry for the stream reaches in Hunting Camp Creek subwatersheds were based on the visual observation of stream channel configurations throughout the watershed and through an analysis of typical stream channel geometry values for these stream types. The stream segment length and slope values for each subwatershed were determined using GIS analysis of digitized streams and digital elevation models (DEMs).

4.5 Selection of a Representative Modeling Period

The selection of a representative modeling period was based on the availability of stream flow and water quality data collected in the Wolf Creek (flow data availability) and Hunting Camp Creek (bacteria data availability) watersheds that cover varying wet and dry time periods. Hourly flow discharge data were available from the USGS gage on Wolf Creek located near Narrows, Virginia (USGS 03175500) from 1908 through 1995 and 1997 through 2003. Water quality data were collected by VADEQ on Hunting Camp Creek during this period; therefore, this time period was selected for modeling purposes. This time period represented varying climatic and hydrologic conditions, including dry, average, and wet periods that typically occur in the area. This was an important consideration because during dry weather and low flow periods, constant direct discharges primarily affect instream concentrations; however, during wet weather and high flow periods, surface runoff delivers nonpoint source bacteria loads to the stream, affecting instream concentrations more so than direct discharges.

4.6 Model Calibration Process

Hydrology and water quality calibration were performed in sequence, since water quality modeling is dependent on an accurate hydrology simulation. Hydrology was the first model component calibrated. The hydrology calibration involved a comparison of the model results for the Wolf Creek reference watershed to stream flow observations at the USGS gage located on Wolf Creek near Narrows, Virginia. Water quality calibration was then conducted for the Hunting Camp Creek watershed (subwatersheds 5-9).

The Wolf Creek reference watershed model was calibrated using daily stream flow data from USGS gage 03175500. Model calibration years were selected using the following four criteria:

1. Completeness of the weather data available for the selected period.
2. Representation of low-flow, average-flow, and high-flow water years.
3. Consistency of selected period with key model inputs (i.e. land use coverage)
4. Quality of initial modeled versus observed data correlation

Based on a review of these four selection criteria, a calibration period beginning in 2000 and ending in the fall of 2003 was chosen. The MRLC land use coverage used in the model was developed during the mid 1990s, therefore, the selected calibration periods are consistent with this key model input. The model was validated for long-term and seasonal representation of hydrologic trends using a 7.75-year period (1/1/1997-9/30/2003).

Model calibration was performed using the error statistics criteria specified in HSPEXP, temporal comparisons, and comparisons of seasonal, high flows, and low flows. Calibration involved the adjustment of infiltration, subsurface storage, evapotranspiration, surface runoff, and interception storage parameters. After adjusting the appropriate parameters within acceptable ranges, good correlations were found between model results and observed data. Hydrology calibration and validation results are shown in Figures 4.3 through 4.8 and Tables 4.6 through 4.8.

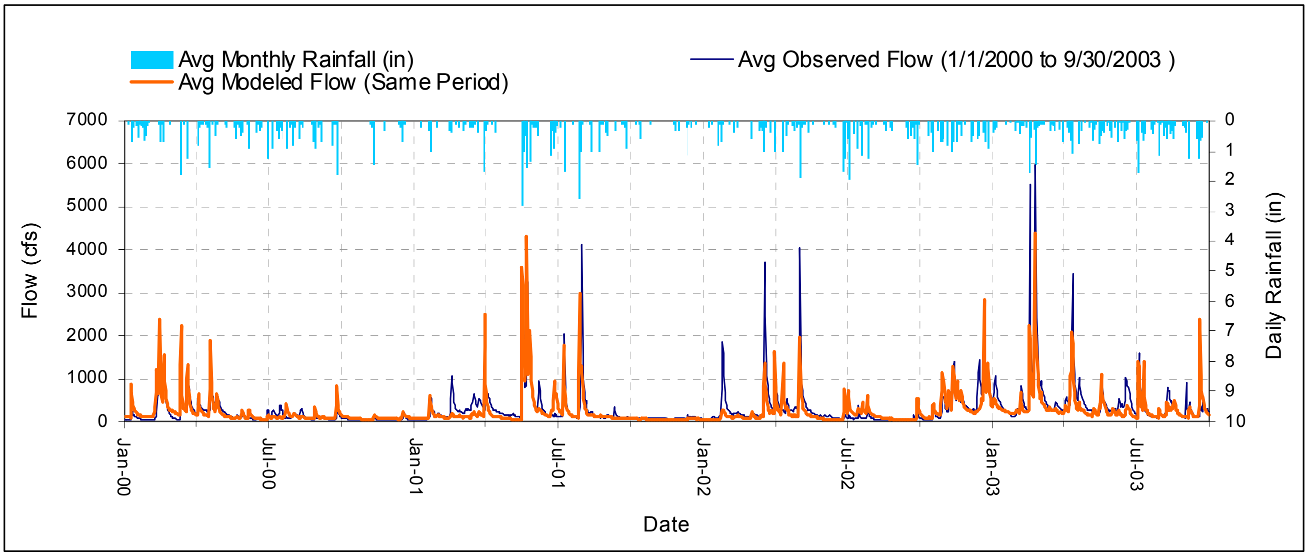

Figure 4.3 Daily flow calibration comparison for calendar years 2000-2003 at USGS 03175500

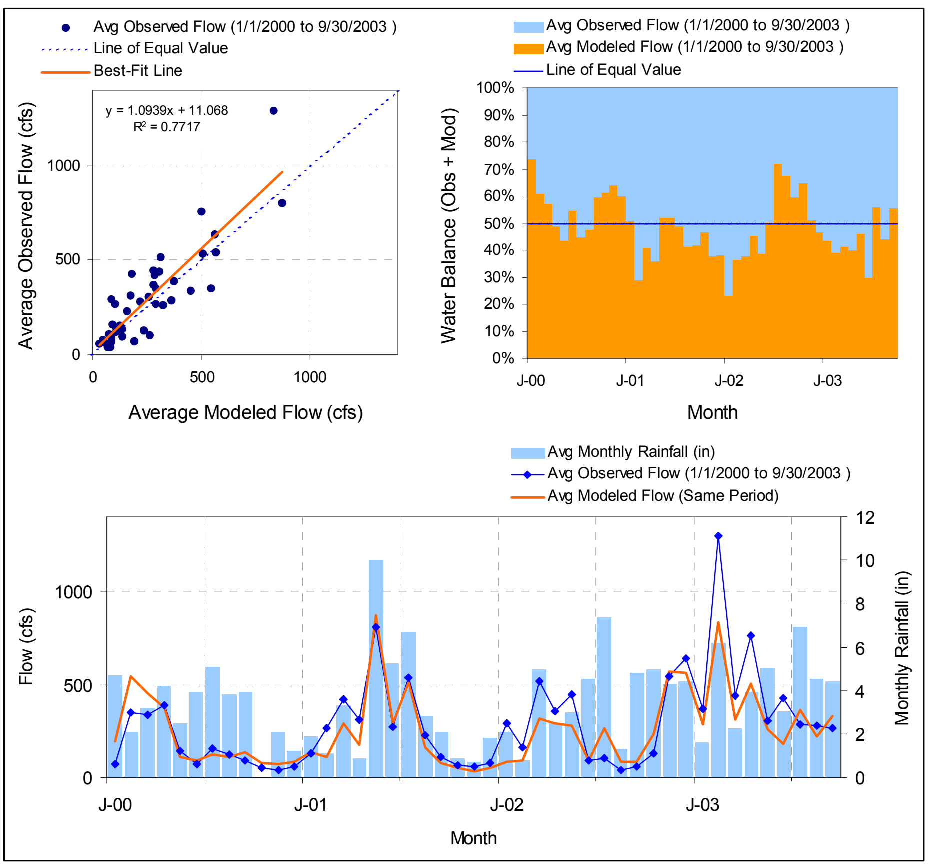

Figure 4.4 Monthly flow calibration for calendar years 2000-2003 at USGS 03175500

Table 4.6 Error statistics for calibration calendar years 2000-2003

LSPC Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM SUBBASIN 1 3.75-Year Analysis Period: 1/1/2000 - 9/30/2003 Flow volumes are (inches/year) for upstream drainage area		USGS 03175500 WOLFE CREEK NEAR NARROWS, VIRGINIA Giles County, Virginia Hydrologic Unit Code 05050002 Latitude 37°18'20", Longitude 80°51'00" NAD27 Drainage area 223.00 square miles	
Total Simulated In-stream Flow:	**103.38**	Total Observed In-stream Flow:	**117.27**
Total of simulated highest 10% flows:	**47.25**	Total of Observed highest 10% flows:	**51.44**
Total of Simulated lowest 50% flows:	**15.32**	Total of Observed Lowest 50% flows:	**14.92**
Simulated Summer Flow Volume (months 7-9):	**22.73**	Observed Summer Flow Volume (7-9):	**20.93**
Simulated Fall Flow Volume (months 10-12):	**15.92**	Observed Fall Flow Volume (10-12):	**15.12**
Simulated Winter Flow Volume (months 1-3):	**32.58**	Observed Winter Flow Volume (1-3):	**41.44**
Simulated Spring Flow Volume (months 4-6):	**32.15**	Observed Spring Flow Volume (4-6):	**39.78**
Total Simulated Storm Volume:	**45.77**	Total Observed Storm Volume:	**49.14**
Simulated Summer Storm Volume (7-9):	**10.14**	Observed Summer Storm Volume (7-9):	**9.51**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	**-13.44**	**10**		
Error in 50% lowest flows:	2.63	10		
Error in 10% highest flows:	-8.85	15		
Seasonal volume error - Summer:	7.94	30		
Seasonal volume error - Fall:	5.02	30		
Seasonal volume error - Winter:	-27.20	30		
Seasonal volume error - Spring:	-23.74	30		
Error in storm volumes:	-7.37	20		
Error in summer storm volumes:	6.24	50		

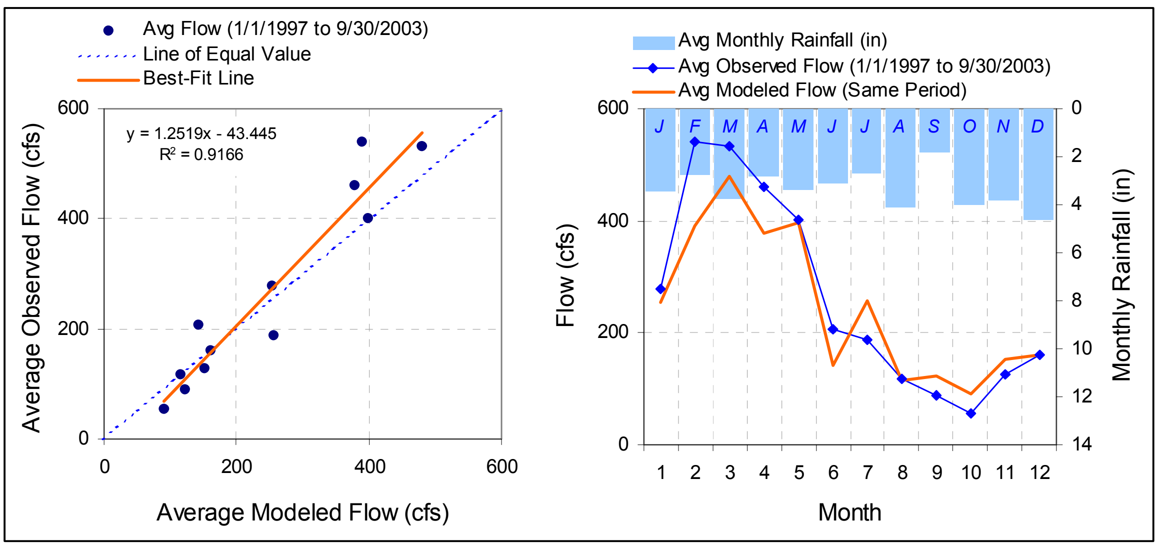

Figure 4.5 Annualized composite validation at USGS03175500 (Calendar Years 1997-2003)

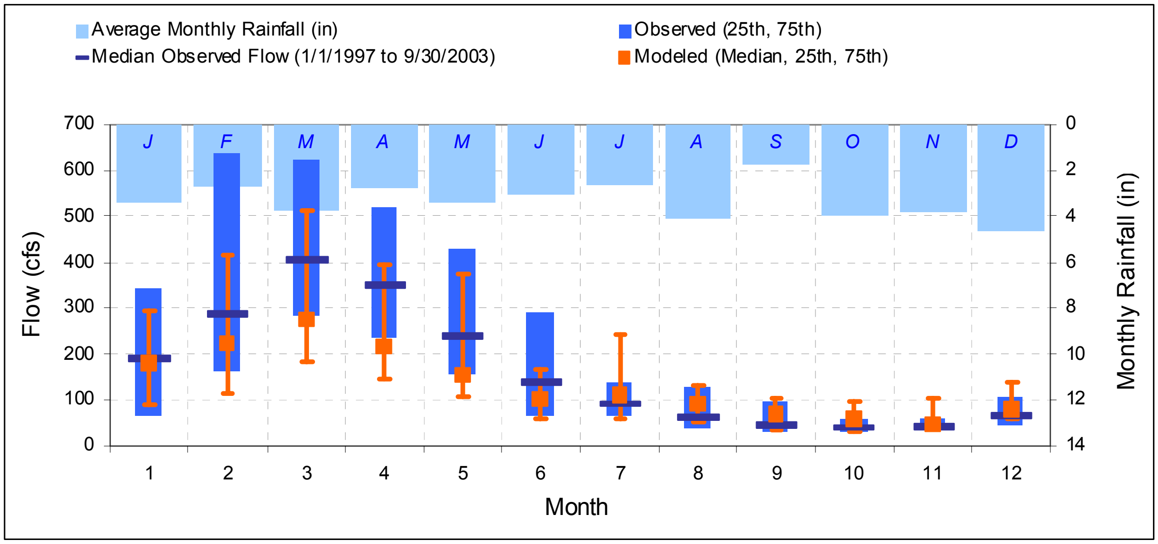

Figure 4.6 Annualized composite validation at USGS03175500 for seasonal trend analysis (Calendar Years 1997-2003)

Table 4.7 Summary statistics for Annualized validation at USGS03175500

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	279.54	191.00	66.00	345.00	254.23	181.11	88.56	295.09
Feb	541.11	289.00	164.00	637.00	389.96	221.43	113.95	415.70
Mar	531.86	404.00	286.00	623.00	480.20	274.69	182.05	509.64
Apr	461.47	351.50	236.25	521.25	378.22	215.22	144.23	393.79
May	402.00	239.00	155.00	429.00	397.44	154.96	107.41	371.63
Jun	206.95	136.00	66.00	292.00	141.95	102.56	57.74	165.32
Jul	186.83	91.00	67.00	139.00	256.30	109.86	57.59	242.83
Aug	116.72	63.00	37.00	129.00	115.86	90.03	52.02	129.29
Sep	89.04	47.00	29.25	99.50	122.94	67.15	31.81	103.66
Oct	55.55	40.00	28.00	59.00	89.77	58.91	30.46	96.69
Nov	126.94	42.00	35.00	59.00	151.90	45.07	34.53	104.66
Dec	161.74	66.00	46.00	108.00	161.62	78.97	58.67	137.66

Table 4.8 Error statistics for validation period (Calendar Years 1997-2003)

LSPC Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM SUBBASIN 1 6.75-Year Analysis Period: 1/1/1997 - 9/30/2003 Flow volumes are (inches/year) for upstream drainage area		USGS 03175500 WOLFE CREEK NEAR NARROWS, VIRGINIA Giles County, Virginia Hydrologic Unit Code 05050002 Latitude 37°18'20", Longitude 80°51'00" NAD27 Drainage area 223.00 square miles		
Total Simulated In-stream Flow:	**102.17**	Total Observed In-stream Flow:		**109.81**
Total of simulated highest 10% flows:	**48.51**	Total of Observed highest 10% flows:		**47.65**
Total of Simulated lowest 50% flows:	**13.50**	Total of Observed Lowest 50% flows:		**12.17**
Simulated Summer Flow Volume (months 7-9):	**17.78**	Observed Summer Flow Volume (7-9):		**14.11**
Simulated Fall Flow Volume (months 10-12):	**12.36**	Observed Fall Flow Volume (10-12):		**10.56**
Simulated Winter Flow Volume (months 1-3):	**39.41**	Observed Winter Flow Volume (1-3):		**47.16**
Simulated Spring Flow Volume (months 4-6):	**32.62**	Observed Spring Flow Volume (4-6):		**37.98**
Total Simulated Storm Volume:	**47.41**	Total Observed Storm Volume:		**42.60**
Simulated Summer Storm Volume (7-9):	**8.48**	Observed Summer Storm Volume (7-9):		**5.90**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-7.47	10		
Error in 50% lowest flows:	9.81	10		
Error in 10% highest flows:	1.77	15		
Seasonal volume error - Summer:	20.65	30		
Seasonal volume error - Fall:	14.62	30		
Seasonal volume error - Winter:	-19.68	30		
Seasonal volume error - Spring:	-16.43	30		
Error in storm volumes:	10.15	20		
Error in summer storm volumes:	30.42	50		

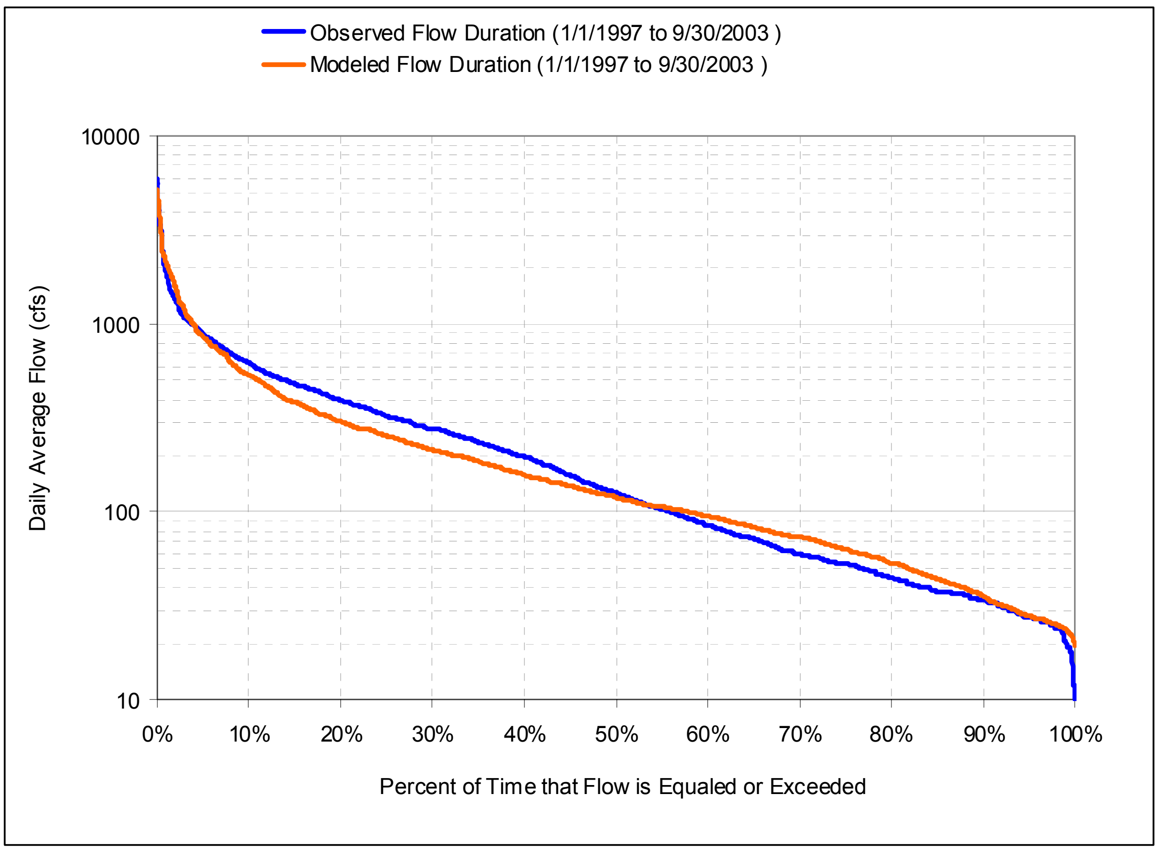

Figure 4.7 Model versus observed flow duration-exceedance curves for 1997 to 2003 at USGS03175500

It is important to note that although the semi-log plot allows for comparative visualization of flows that span several orders of magnitude, this type of graph tends to diminish the differences in high flows, while exaggerating the differences in low flows. The validity of any hydrology calibration must be evaluated using multiple comparisons like those shown previously.

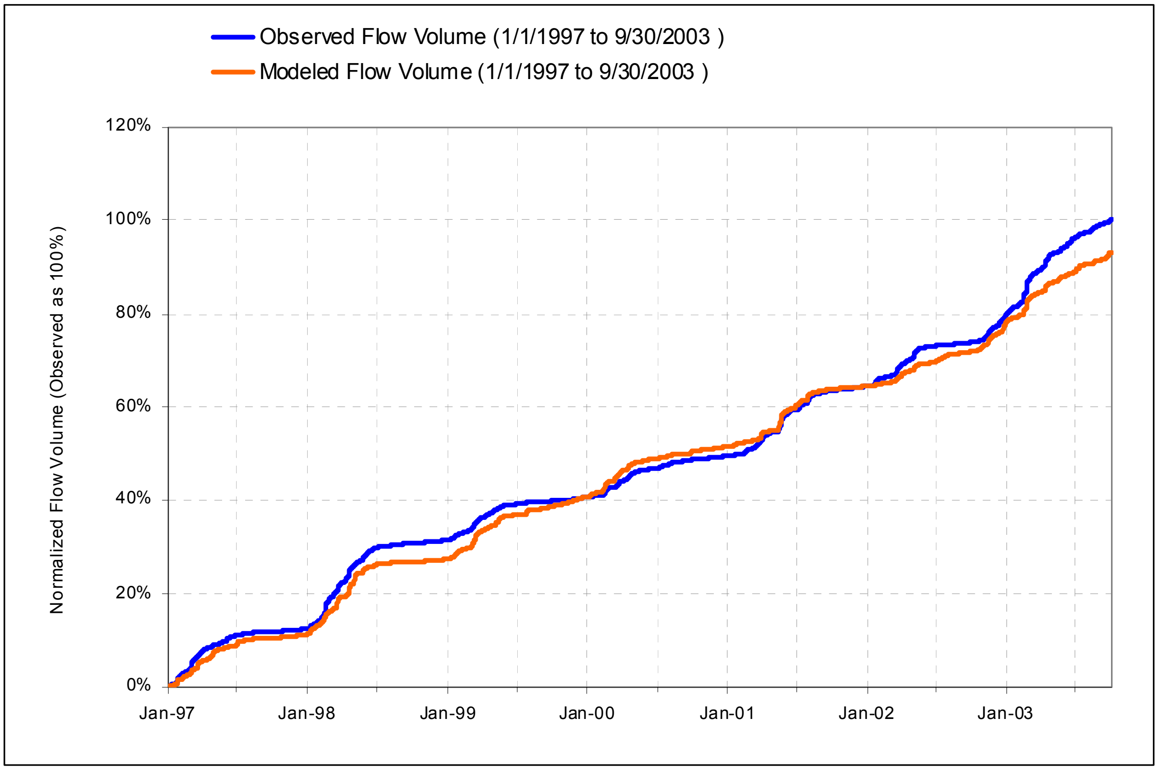

Figure 4.8 Modeled versus observed cumulative flow curve for 1997 to 2003 at USGS03175500

Fecal coliform accumulation and surface loading parameters for land uses were calculated based on contributions from various sources, as discussed in Section 3. After incorporating these model parameters and inputs, as well as contributions from livestock and wildlife point sources, failing septic systems, and background concentrations in the streams, modeled in-stream fecal coliform bacteria concentrations were compared to observed data. The modeled concentrations closely correspond to the observed fecal coliform values, as shown in Figures 4.9 and 4.10. The relative pattern of observed concentration levels is maintained in the modeled concentrations.

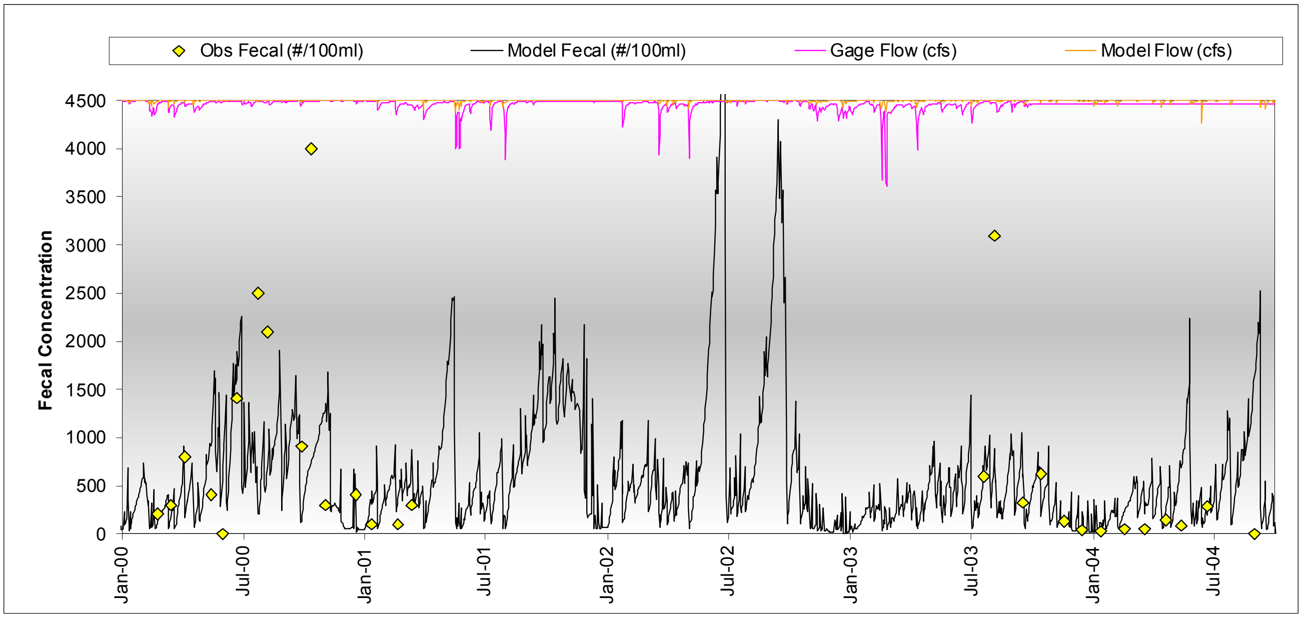

Figure 4.9 Water quality calibration at 9-HCC001.40 on Hunting Camp Creek 2000-2004

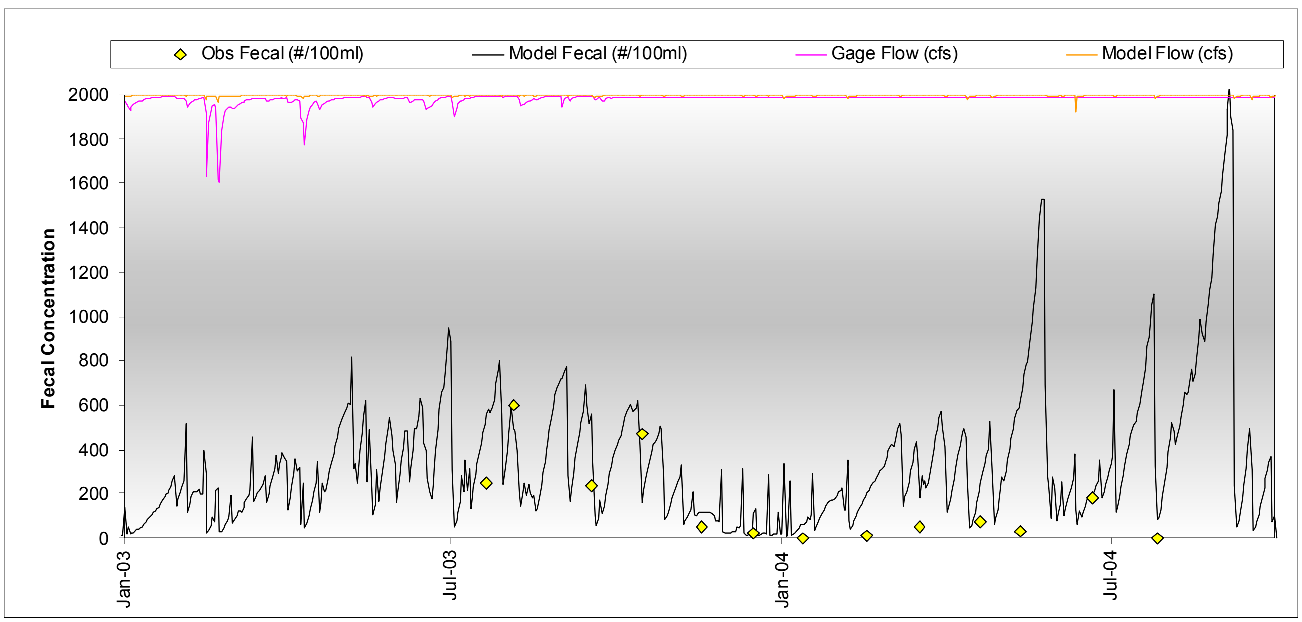

Figure 4.10 Water quality validation at 9-HCC001.40 on Hunting Camp Creek 2003-2004

4.7 Existing Loadings

The model was run for the representative hydrologic period January 1, 1990 through September 30, 2004 (weather data available through this date). The modeling run represents the existing bacteria concentrations and loadings at the watershed outlet. Figure 4.11 shows the existing instantaneous and geometric mean concentrations of *E. coli* for Hunting Camp Creek, using the VADEQ fecal coliform bacteria/*E. coli* translator (VADEQ 2003). These data were compared to the 235 cfu/100mL instantaneous and 126 cfu/100mL geometric mean water quality criteria for *E. coli* to assess the magnitude of in-stream concentrations. Existing *E. coli* loadings by land use category for Hunting Camp Creek are presented in Sections 8. These values represent the contribution of *E. coli* loads from all sources in the watershed.

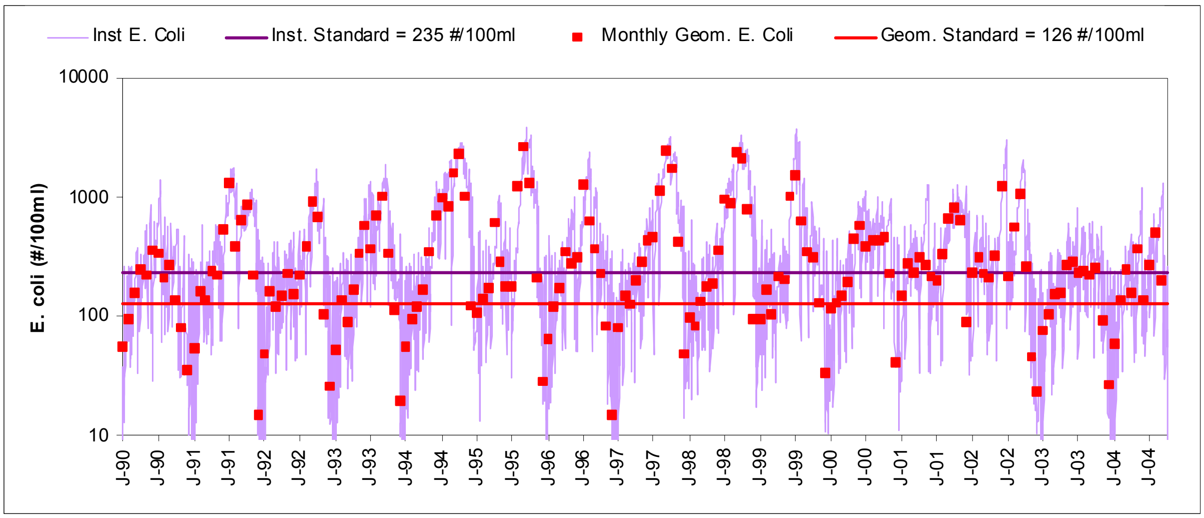

Figure 4.11 Instantaneous and geometric mean concentrations of *E. coli* from 1990 to 2004

SECTION 5

BENTHIC STRESSOR IDENTIFICATION

5.1 Background Information

The Hunting Camp Creek watershed (Virginia WBID: VAS-N31R) is located in the New River Basin (HUC: 05050002) in Bland County, Virginia. The headwaters begin in the Jefferson National Forest and the stream flows in a northeasterly direction through forest and pasture land to its confluence with Wolf Creek. Laurel Creek is the largest tributary to Hunting Camp Creek. The communities of Bastian and Suiter are located in this 20,603 acre watershed.

Hunting Camp Creek was placed on Virginia's Section 303(d) list due to partial support of the Aquatic Life Use and non-support of the Swimmable Use. The impaired segment is 8.45 miles in length and begins at the impoundment on Hunting Camp Creek above the community of Suiter and continues downstream to the confluence with Wolf Creek. The biological (benthic) impairment listing was based on comparing the benthic macroinvertebrate community in Hunting Camp Creek to a reference stream with similar characteristics. Bacteria data collected on Hunting Camp Creek indicate an impairment of the primary contact recreation (swimmable) criteria.

Benthic community assessments conducted on Hunting Camp Creek (DEQ station 9-HCC001.40) indicate a moderate impairment of the benthic community. According to the 2002 303(d) Impaired Waters Fact Sheet, erosion and sedimentation was observed along the stream as it flows through predominately pasture land. This portion of the stream corridor is characterized by denuded banks with evident streambank erosion. Urban development around Bastian is also believed to contribute to the benthic impairment. A new sewage treatment plant at Bastian went online in the summer of 2003, which may have alleviated some of the observed problems.

Virginia's Stream Condition Index (VaSCI) was recently developed by VADEQ, EPA Region III, and Tetra Tech, Inc. This multimetric index was developed for Virginia's non-coastal streams to provide an improved bioassessment tool for determining stream condition. VaSCI results for Hunting Camp Creek and reference stations are presented in Table 5.1. Station locations and other station attributes are presented in Section 5.3. Scores are presented for VADEQ and U.S. Forest Service (USFS) stations.

The VaSCI recommended threshold of impairment is a score of 61. The long-term biomonitoring station on Hunting Camp Creek (9-HCC001.40) averaged a VaSCI score of 57 for the period of record (range: 46-73). An upstream station on Hunting Camp Creek was recently added by VADEQ. This station averaged a score of 54 (range: 49-59). The average score for USFS stations on Hunting Camp Creek and its tributaries was 65 (range: 60-75). Biomonitoring stations that have been used as reference comparisons averaged a score of 73 (range: 60-79).

Table 5.1 VaSCI scores for Hunting Camp Creek and reference stations

Station	Sampling Date	Stream	VaSCI Score
Hunting Camp Creek Watershed			
9-HCC001.40	10/04/1994	Hunting Camp Creek (downstream)	56.19
	05/24/1996		45.93
	10/25/1996		58.77
	05/19/1998		61.57
	11/09/1998		52.10
	05/12/1999		52.12
	10/28/1999		46.70
	11/25/2003		73.23
	05/25/2004		68.30
9-HCC007.83	11/25/2003	Hunting Camp Creek (upstream)	58.50
	05/26/2004		49.41
7004 (USFS)	09/09/1994	Laurel Creek	74.79
7021 (USFS)	07/20/1994	Hunting Camp Creek	59.98
7026 (USFS)	07/18/1994	Little Wolf Creek	60.30
Other Reference Streams			
9-CVR002.47	10/24/1994	Cove Creek	64.49
9-IDI000.55	05/21/1996	Indian Creek	77.02
9-WFC034.82	10/25/1996	Wolf Creek	77.81
9-LAC000.92	05/19/1998	Laurel Creek	79.45
	11/09/1998		73.03
	05/12/1999		68.76
	10/28/1999		79.40
6BMID000.20	11/17/2003	Middle Creek	60.34

5.2 Stressor Identification Process

Biological assessments are useful in detecting impairment, but they do not necessarily identify the cause(s) of impairment. EPA developed the Stressor Identification: Technical Guidance Document to assist water resource managers in identifying stressors or combinations of stressors that cause biological impairment (Cormier et al. 2000). Elements of the stressor identification process were used to evaluate and identify the primary stressors of the benthic community in Hunting Camp Creek. Available water quality, biomonitoring, and other data from the Hunting Camp Creek watershed and reference watersheds were used to help identify candidate causes.

A summary of all available data, monitoring locations, and governing water quality criteria are presented in Section 5.3. Factors that may be responsible for the observed benthic impairment on Hunting Camp Creek are discussed in Section 5.4. Candidate causes were listed to include both probable and relatively unlikely stressors in order to provide a comprehensive review and evaluation of potential stressors. Data analyses and interpretation of results are provided in Sections 5.4 and 5.5.

5.3 Monitoring Data Summary

5.3.1 Water Quality Criteria

Hunting Camp Creek is classified as a Natural Trout Water (Class VI) in Virginia's Water Quality Standards (9 VAC 25-260-540). Numeric criteria for dissolved oxygen (DO), pH, and maximum temperature for Class VI waters are shown in Table 5.2.

Table 5.2 Virginia's numeric criteria for Class VI waters

Dissolved Oxygen (mg/l)		pH (standard units)	Maximum Temperature (^{o}C)
Minimum	Daily Average		
6.0	7.0	6.0-9.0	20

5.3.2 Monitoring Summary

Data collected on Hunting Camp Creek and tributaries include VADEQ Ambient Water Quality Monitoring (AWQM), special study, sediment, and biomonitoring data; GMU water quality data; U.S. Forest Service (USFS) water quality and biomonitoring data. In addition, the Virginia Department of Game and Inland Fisheries (DGIF) conducted a fish survey in 1999. VADEQ AWQM data are typically collected on a monthly or bi-monthly basis and biomonitoring data are collected in the spring and fall of each year. USFS samples various streams in the Jefferson National Forest, including Hunting Camp Creek, Laurel Creek, and Little Wolf Creek. GMU personnel also sampled these streams as part of the TMDL study in June 2003. VADEQ, USFS, and GMU monitoring stations located in the Hunting Camp Creek watershed are presented in Table 5.3 and shown in Figure 5.1. The data period shown in Table 5.3 includes field parameters collected during biomonitoring site visits.

Table 5.3 Monitoring stations - Hunting Camp Creek watershed

Station [1]	Organization	Station Type	Location	Data Period
9-HCC000.16	DEQ	SS	North of Bastian off access road	1 visit: 8/19/03 (Diurnal DO monitoring) [2]
9-HCC000.29	DEQ	No data [5]	Rt. 52 near Bastian Union Church	No data [5]
9-HCC001.40	DEQ	AWQM, Bio, Sediment, SS, BST	Bridge #1009 on Rt. 52/21 off I77	1 visit: 8/19/03 (Diurnal DO monitoring) [2] 52 records: 10/4/94 – 7/22/04 [4] BST: 12 monthly samples Bio: 7 visits (10/4/94 – 10/28/99)
9-HCC005.57	DEQ	AWQM, BST	Bridge #6067 on Rt. 646 off Rt. 615	7 visits-38 records: 7/28/03 – 7/27/04 (Bimonthly sampling – field parameters, solids, nutrients, E. coli-limited data) [3] 23 records 7/21/03 – 7/27/04 [2] BST: 12 monthly samples

Station [1]	Organization	Station Type	Location	Data Period
9-HCC006.78	DEQ	SS	Bridge @ community of Suiter	1 visit: 8/19/03 (Diurnal DO monitoring) [2]
9-HCC007.83	DEQ	Bio, SS	Last bridge before Rt. 618 is gated	1 visit: 8/19/03 (Diurnal DO monitoring) [2]
7021	USFS	Bio	Upstream of impoundment in headwaters	7/20/94
7004 (Laurel Creek)	USFS	WQ, Bio	Laurel Creek	9/9/94
7026 (Little Wolf Creek)	USFS	WQ, Bio	Near stream mouth	7/18/94
HC1 (Little Wolf Creek – same location as USFS station 7026)	GMU	WQ	Little Wolf Creek @ intersection with Appalachian Trail off Rt. 615	1 visit: 6/26/03
HC2 (Laurel Creek)	GMU	WQ	Laurel Creek @Rt. 615	1 visit: 6/26/03
HC3 (same location as DEQ station 9-HCC005.57)	GMU	WQ	Hunting Camp Creek below confluence with Laurel Creek @ Rt. 646	1 visit: 6/26/03
HC4 (same location as DEQ station 9-HCC001.40)	GMU	WQ	Hunting Camp Creek off Rt. 52 @ Bastian Union Church Park (DEQ Station)	1 visit: 6/26/03

Notes:

Station Type: Bio = Biomonitoring
AWQM = Ambient Water Quality Monitoring
WQ = Water Quality Monitoring – selected parameters
Sediment = Sediment Monitoring
SS = TMDL Special Study
BST = Bacteria Source Tracking

[1] all stations are located on Hunting Camp Creek, unless otherwise noted
[2] data obtained from DEQ website – View DEQ's ambient monitoring data by station, search by stream.
[3] data obtained from DEQ website – Water Quality Monitoring Data Retrieval Application, search by stream. Retrieval did not capture stations 9-HCC000.29 and 9-HCC001.40
[4] data obtained from DEQ website – Interactive map feature (only Station 9-HCC001.40 shown)
[5] data obtained from DEQ website – Water Quality Monitoring Data Retrieval Application, search by basin

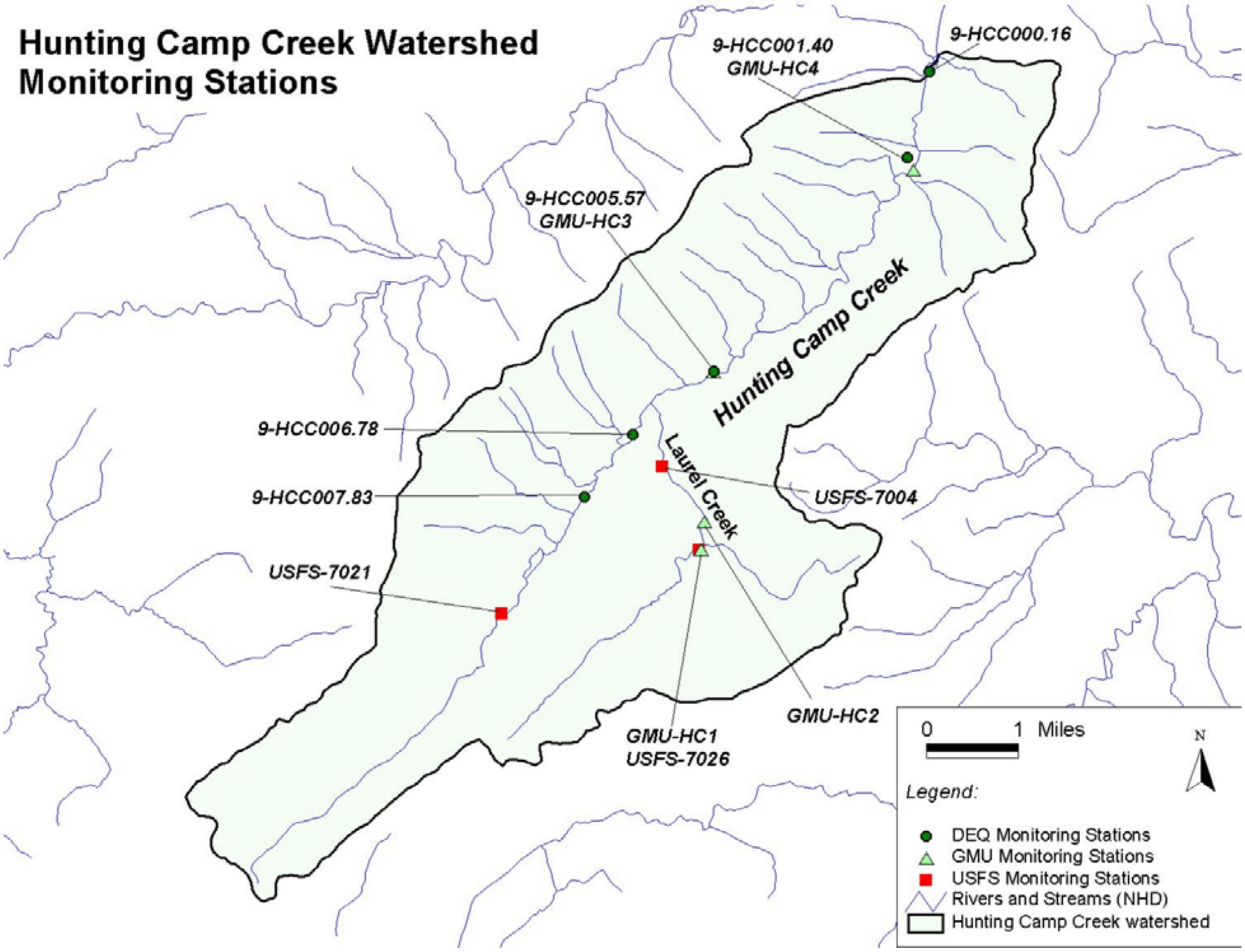

Figure 5.1 Hunting Camp Creek watershed and monitoring stations

Biomonitoring reference stations that have been used to assess the condition of the benthic macroinvertebrate community in Hunting Camp Creek are listed in Table 5.4. Hunting Camp Creek was assessed as "moderately impaired" by VADEQ based on a comparison of the Rapid Bioassessment II (RBP II) scores for Hunting Camp Creek and the corresponding reference station. The final assessment for the 5/19/98 sampling event was "slightly impaired" based on best professional judgement of the regional biologist, according to the Biological Monitoring Survey data sheet. A final assessment of "moderately impaired" was recorded for all other sampling events.

Table 5.4 Biomonitoring reference stations for 9-HCC001.40

Station	Stream	Type	Location	Used as Reference [1]	Nearby WQ Stations
9-CVR002.47	Cove Creek	Bio	Off Rt. 61 on Turley Farm Rd.	10/4/94	9-CVR003.88
9-IDI000.55	Indian Creek	Bio	Rt. 621	5/24/96	N/A
9-WFC034.82	Wolf Creek	Bio	at Camp Roland	10/25/96	9-WFC024.57 9-WFC039.16 9-WFC050.16

Station	Stream	Type	Location	Used as Reference [1]	Nearby WQ Stations
9-LAC000.92	Laurel Creek	Bio	Rocky Gap	9/9/98, 5/12/99, 8/19/99, 10/28/99	N/A
6BMID000.20	Middle Creek	Bio	Rt. 621 Bridge	Under review as potential reference	N/A
9-HCC007.83	Hunting Camp Creek	Bio	Last bridge before Rt. 618 is gated	Under review as potential upstream reference	See Table 2

[1] date listed is the corresponding Hunting Camp Creek sampling date

A statistical data summary for selected water quality parameters is presented in Table 5.5. Time-series plots for these parameters are presented in the following section.

Table 5.5 Water quality summary statistics

Station	Parameter	N	mean	median	min	max
9-HCC000.16	pH (field probe)	1	7.19	7.19	7.19	7.19
	Dissolved oxygen (field), mg/l	1	7.89	7.89	7.89	7.89
	Temperature, degrees C	1	19.50	19.50	19.50	19.50
	Conductivity, field	1	73.00	73.00	73.00	73.00
9-HCC001.40 / HC4	pH (field probe)	51	7.13	7.13	6.10	8.82
	Dissolved oxygen (field), mg/l	51	10.36	9.73	7.49	15.55
	Temperature, degrees C	51	11.99	12.70	-0.12	24.30
	Conductivity, field	50	90.84	72.00	32.00	290.00
	BOD5, mg/l	13	2.00	2.00	2.00	2.00
	Total Phosphorus, mg/l	27	0.0137	0.0100	0.01000	0.030
	Ortho phosphate, mg/l	15	0.0133	0.0100	0.01000	0.020
	Nitrates, mg/l	16	0.0998	0.0800	0.04000	0.286
	Nitrites, mg/l	15	0.0107	0.0100	0.01000	0.020
	Nitrite plus nitrate, mg/l	12	0.1100	0.0950	0.04000	0.380
	Total Ammonia, mg/l	28	0.0416	0.0400	0.04000	0.084
	TSS, mg/l	28	3.14	3.00	1.00	6.00
	Turbidity, NTU	28	3.21	2.27	0.64	11.20
	Fecal, MFM	26	739	300	20	4000
	E. coli	12	224	90	2	800
9-HCC005.57 / HC3	pH (field probe)	22	7.49	7.37	6.96	8.23
	Dissolved oxygen (field), mg/l	22	9.84	9.27	7.24	13.16
	Temperature, degrees C	22	15.07	16.46	-0.19	25.40
	Conductivity, field	22	54.04	44.95	28.00	145.00
	Total Phosphorus, mg/l	9	0.0137	0.01000	0.01000	0.0333
	Nitrates, mg/l	1	0.5870	0.58700	0.58700	0.5870
	Nitrite plus nitrate, mg/l	8	0.0938	0.09500	0.04000	0.1500
	Total Ammonia, mg/l	9	0.0455	0.04000	0.04000	0.0895
	TSS, mg/l	9	2.89	3.00	2.00	3.00
	Turbidity, NTU	9	1.57	1.20	0.10	3.00
	Fecal, MFM	12	164	60	1	600
	E. coli	14	202	72	1	780

Station	Parameter	N	mean	median	min	max
9-HCC006.78	pH (field probe)	1	6.68	6.68	6.68	6.68
	Dissolved oxygen (field), mg/l	1	7.80	7.80	7.80	7.80
	Temperature, degrees C	1	18.90	18.90	18.90	18.90
	Conductivity, field	1	25.00	25.00	25.00	25.00
9-HCC007.83	pH (field probe)	1	6.64	6.64	6.64	6.64
	Dissolved oxygen (field), mg/l	1	8.09	8.09	8.09	8.09
	Temperature, degrees C	1	19.60	19.60	19.60	19.60
	Conductivity, field	1	22.00	22.00	22.00	22.00
HC1	pH (field probe)	1	7.60	7.60	7.60	7.60
	Dissolved oxygen (field), mg/l	1	10.04	10.04	10.04	10.04
	Temperature, degrees C	1	16.30	16.30	16.30	16.30
	Conductivity, field	1	22.30	22.30	22.30	22.30
	Total Phosphorus, mg/l	1	0.03409	0.03409	0.03409	0.03409
	Nitrates, mg/l	1	0.55400	0.55400	0.55400	0.55400
	Total Ammonia, mg/l	1	0.09309	0.09309	0.09309	0.09309
	TSS, mg/l	1	1.80	1.80	1.80	1.80
	Turbidity, NTU	1	2.65	2.65	2.65	2.65
HC2	pH (field probe)	1	8.21	8.21	8.21	8.21
	Dissolved oxygen (field), mg/l	1	10.23	10.23	10.23	10.23
	Temperature, degrees C	1	16.70	16.70	16.70	16.70
	Conductivity, field	1	62.90	62.90	62.90	62.90
	Total Phosphorus, mg/l	1	0.06440	0.06440	0.06440	0.06440
	Nitrates, mg/l	1	0.33500	0.33500	0.33500	0.33500
	Total Ammonia, mg/l	1	0.08430	0.08430	0.08430	0.08430
	TSS, mg/l	1	1.40	1.40	1.40	1.40
	Turbidity, NTU	1	1.74	1.74	1.74	1.74

5.4 Stressor Analysis Summary

Selected parameters were plotted to examine spatial trends and to compare impaired and reference stream conditions (Figures 5.2 through 5.24; and Figures 5.38 through 5.41). Water quality monitoring data collected by VADEQ and GMU were analyzed using time-series observation plots presented in this section. Time series plots are shown for the period for record and the most recent dataset (2003-2004) for each station. Water quality data collected during biomonitoring field visits were included in these plots. Additionally, some data were available from USFS stations in the watershed, which were incorporated into the analysis.

5.4.1 Water Temperature - unlikely stressor

Temperature affects the metabolic rates of aquatic organisms, photosynthesis of aquatic plants, parasites, pathogens, and can influence the toxicity of some pollutants. In addition, higher water temperatures reduce the oxygen saturation capacity of the water, which can have negative effects on organisms that require a certain amount of dissolved oxygen to sustain life.

Humans can influence water temperature by direct thermal pollution, altering land cover and land use within a watershed, or removing vegetation within the riparian zone. Temperature can also be increased by increasing turbidity, which allows more solar radiation to be absorbed by the water.

Surface water temperature data for the Hunting Camp Creek watershed are shown in Figures 5.2 and 5.3. Several observations exceeded the Class VI maximum criteria (20 degrees Celsius) at DEQ stations 9-HCC001.40 and 9-HCC005.57. The single highest observation was recorded at DEQ station 9-HCC005.57. These recent temperature violations will result in the listing of Hunting Camp Creek as impaired due to high stream temperatures on the 2006 303(d) list. These stations are located in pastured and residential open channel areas with minimal riparian vegetative cover. This lack of shading has led to increased water temperature levels. There are no known thermal discharges into the stream. The temperature criteria specified in Virginia's Water Quality Standards were developed based on the relationship between water temperature and fish community impacts. Extreme water temperatures may also impact the benthic community; however, these data do not suggest consistently high water temperatures that could affect community composition. As a result, temperature is not considered a stressor to the benthic community. Note that BMP implementation to address other potential stressors, such as sedimentation, typically includes riparian plantings that provide necessary shading.

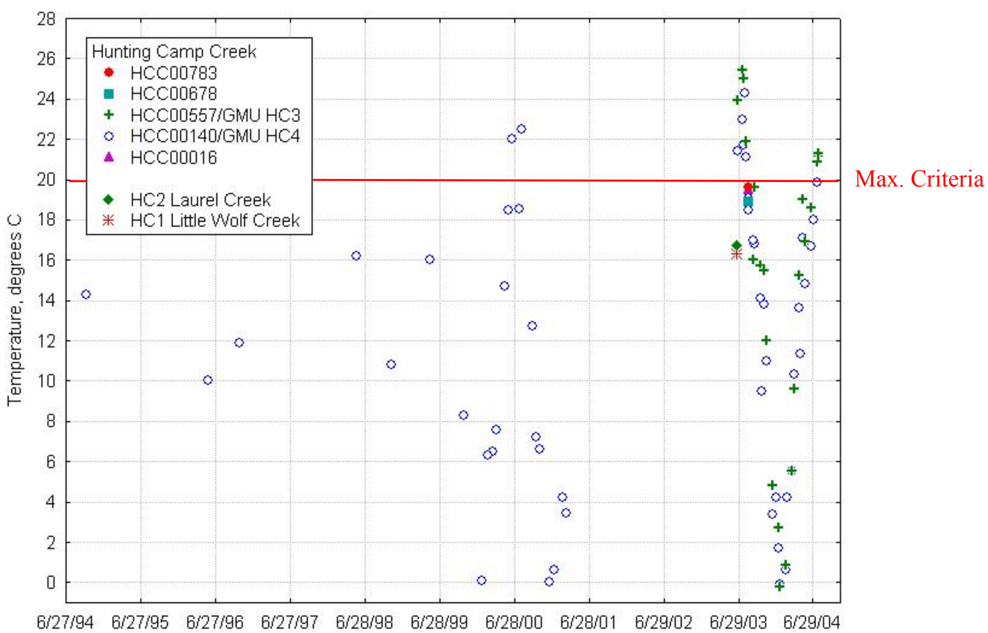

Figure 5.2 Time-series temperature values (period of record)

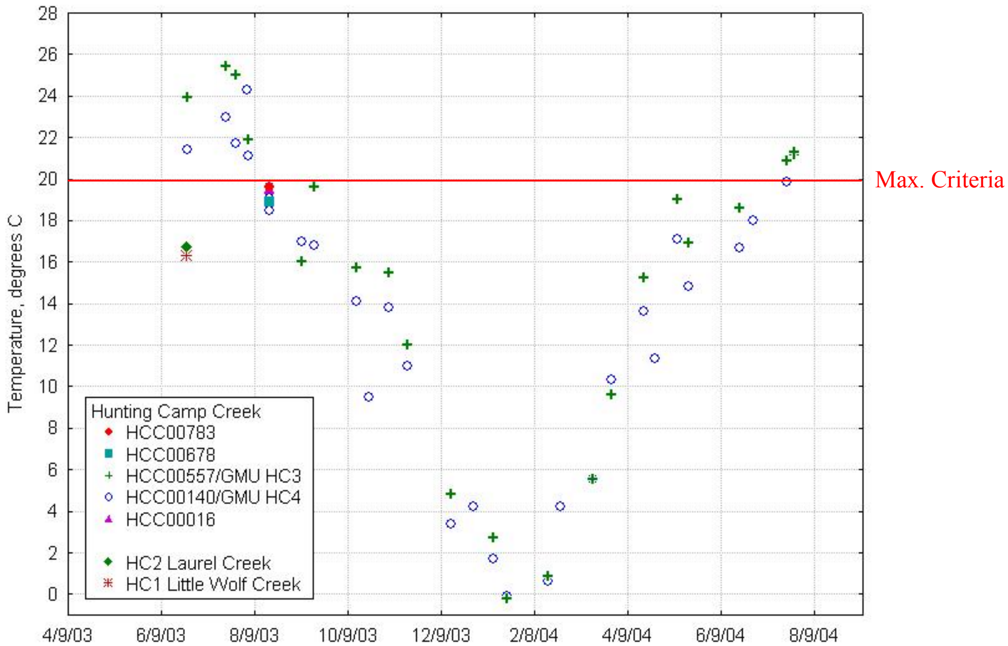

Figure 5.3 Time-series temperature values (2003-2004)

5.4.2 pH - eliminated stressor

pH can negatively affect organisms when it is both too high and too low. As a result, an appropriate pH level for healthy stream ecosystems is often considered to be between 6.0 and 9.0 standard units. Low pH conditions (acidity) can be caused by various sources including runoff, acidic precipitation and deposition, and point source discharges. High pH is often associated with excess primary production of algae, which alters the balance of carbonates in the water. In Virginia streams, low pH is typically a more common problem than high pH.

pH levels outside the acceptable range can cause numerous secondary impacts as well. For example, when pH is low, aluminum ions can be mobilized and attach to the gills of freshwater organisms, resulting in decreased respiratory efficiency and, in some cases, mortality. In the case of high pH, the level of unionized ammonia in the water column increases resulting in potential toxic impacts to aquatic organisms. Reduced emergence and mortality of stoneflies, mayflies, and dragonflies at pH levels greater than 9.5 has also been noted in freshwater studies (NAS/NAE 1972).

pH data for the Hunting Camp Creek watershed are shown in Figures 5.4 and 5.5. All measurements were within the acceptable range for Class VI waters (6.0-9.0). DEQ/GMU station 9-HCC001.40/HC4 demonstrated the largest fluctuation in pH conditions.

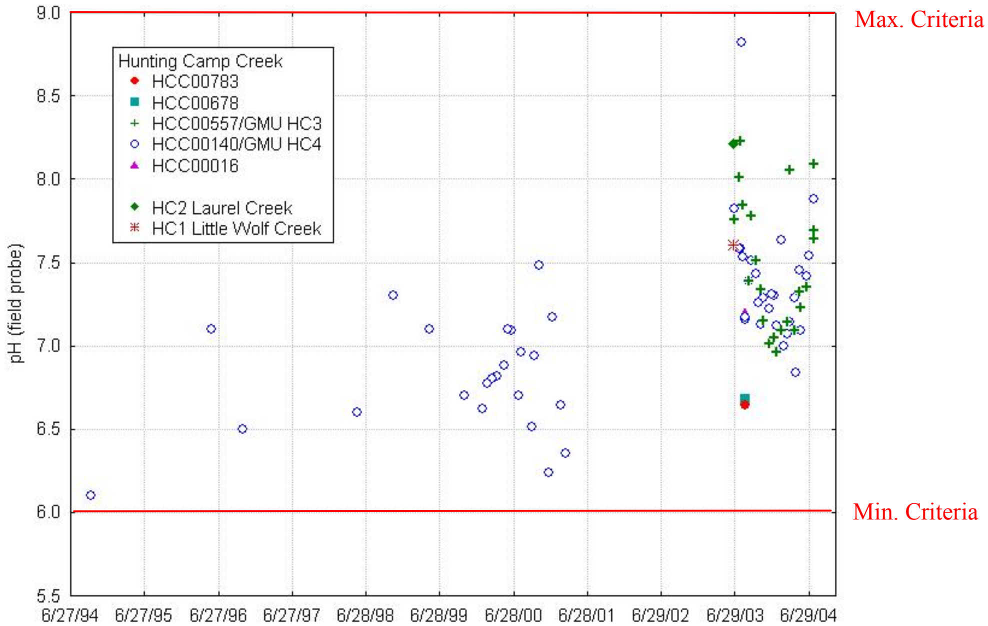

Figure 5.4 Time-series pH values (period of record)

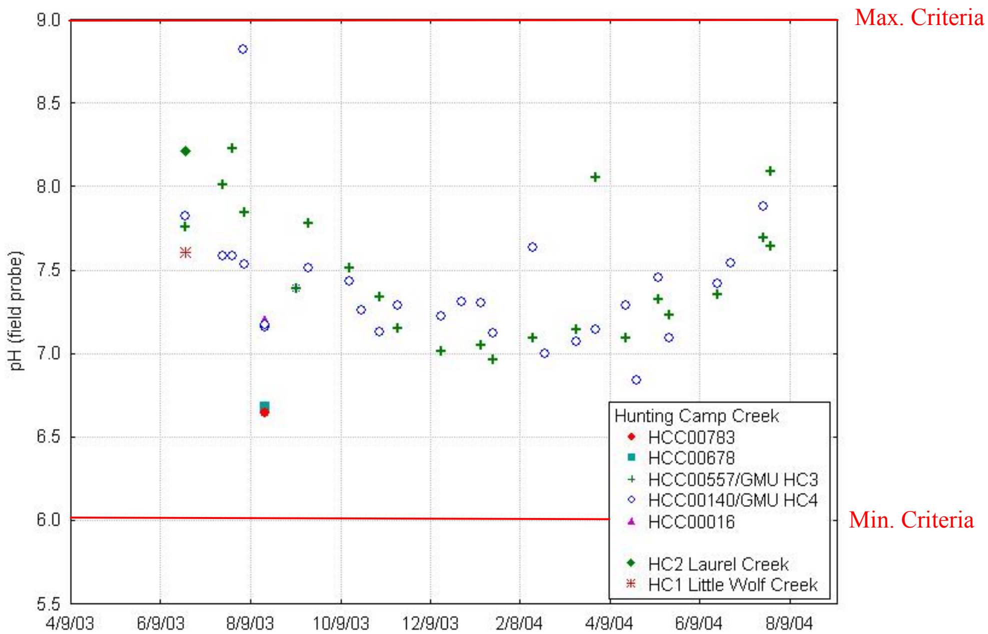

Figure 5.5 Time-series pH values (2003-2004)

The USFS also recorded pH data at stations 7004 (Laurel Creek) and 7026 (Little Wolf Creek) in 1994. These measurements were also in the acceptable pH range for these streams: Station 7004 - pH = 7.45; Station 4026 – pH = 7.33. These data are not shown in the above figures. Abnormal pH levels were not observed; therefore pH was eliminated as a possible stressor.

5.4.3 Dissolved Oxygen - eliminated stressor

Organic enrichment can cause low dissolved oxygen (DO) levels which stress benthic organisms. In general, high nitrogen and phosphorus levels can lead to increased production of algae and macrophytes, which can result in the depletion of oxygen in the water column through metabolic respiration. In addition, at higher water temperatures the concentration of dissolved oxygen is lower because the solubility of oxygen (and other gases) decreases with increasing temperature. Higher water temperatures can be caused by the loss of shading, higher evaporation rates, reduced stream flow, and other factors.

Aquatic organisms, including benthic macroinvertebrates, are dependent upon an adequate concentration of dissolved oxygen. Less tolerant organisms generally cannot survive or are outcompeted by more tolerant organisms under low dissolved oxygen conditions. This process reduces diversity and alters community composition from a natural state. Aquatic insects and other benthic organisms serve as food items for fishes, therefore, alterations in the benthic community can impact fish feeding ecology (Hayward and Margraf 1987; Leach et al. 1977).

Primary producers (algae and macrophytes) produce oxygen during the day through photosynthesis and use oxygen at night through respiration. This diel photosynthesis/respiration cycle results in higher DO concentrations during the day and lower concentrations at night. VADEQ and GMU water quality data were compared to the daily average (7.0 mg/L) and minimum (6.0 mg/L) DO criteria listed in Virginia's Water Quality Standards to help determine if low DO conditions occur in Hunting Camp Creek. DO concentrations measured at VADEQ and GMU monitoring stations were above established criteria (Figures 5.6 and 5.7).

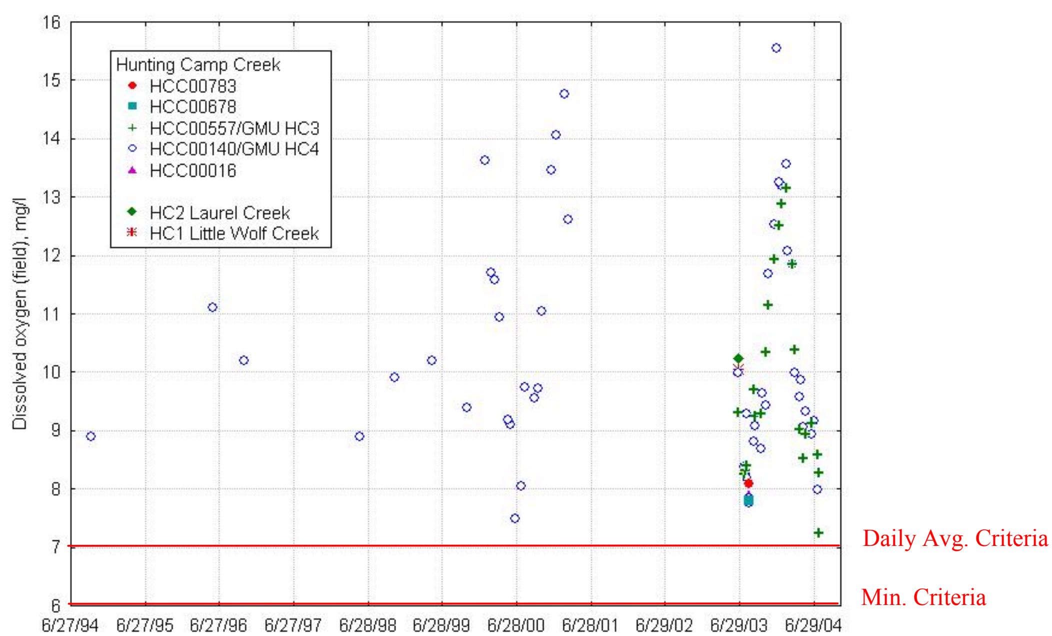

Figure 5.6 Time-series DO values (period of record)

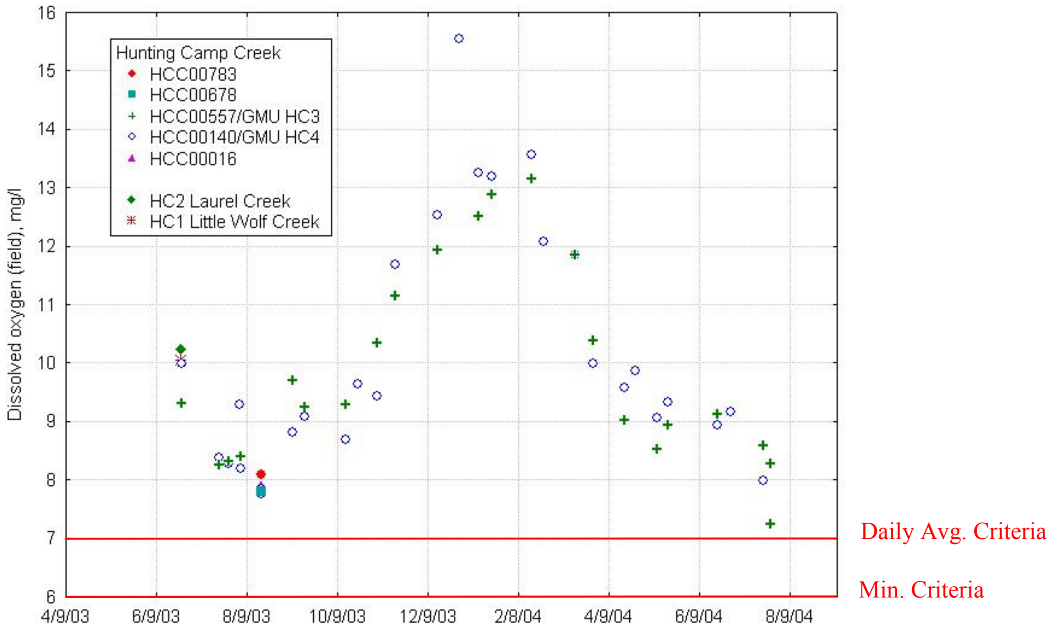

Figure 5.7 Time-series DO values (2003-2004)

These data include DO measurements that were recorded by VADEQ in the early morning hours at several stations in watershed on 8/19/03 (between 5:00 and 5:45 am). DO conditions are typically lowest during summer months in the early morning hours due to higher temperatures and lower flow. These data also do not indicate low DO conditions in Hunting Camp Creek. Based on these data, low DO was eliminated as a possible impairment cause.

5.4.4 Organic Matter - eliminated stressor

Excess organic matter can directly interfere with the habitat of numerous benthic organisms. In excess amounts, particulate organic matter (POM) can clog the substrate, covering or filling acceptable benthic habitat. Dissolved organic matter (DOM) affects water clarity and nutrient availability. Furthermore, organic matter can alter the pH of water through decomposition and the release of excess nutrients into the aquatic environment can have further negative consequences.

Biochemical oxygen demand (BOD5) is the measure of the amount of oxygen consumed by microorganisms during decomposition of organic matter. Therefore, this parameter is a good indicator of the amount of organic matter contributed to a waterbody. BOD5 was only measured at VADEQ station 9-HCC001.40 during the period of record. All measurements were below the detection limit of 2 mg/l (Figure 5.8, detection limit shown).

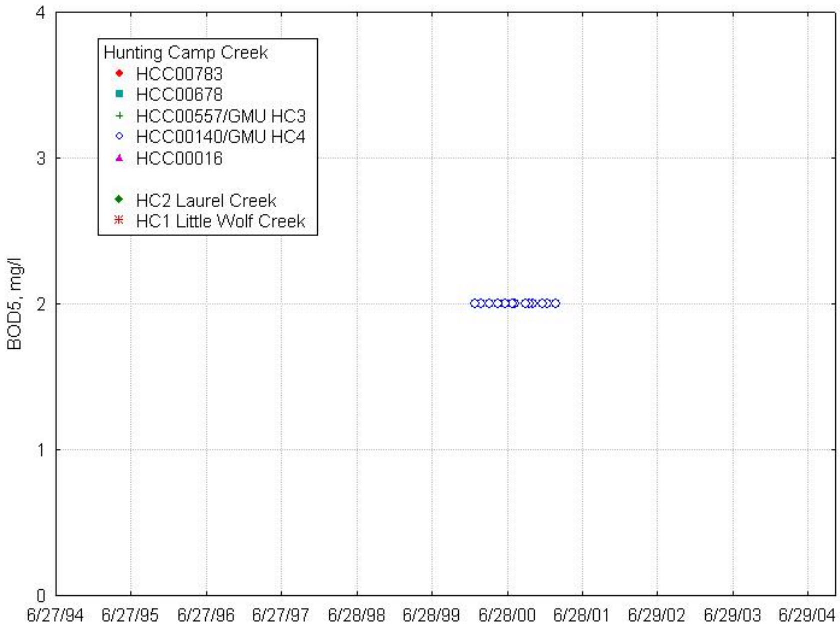

Figure 5.8 Time-series BOD5 values (period of record)

The chronic presence of high bacteria levels is also a good indicator of potential organic enrichment problems that may lead to water quality and habitat problems. Failing septic systems and straight pipes, runoff from livestock areas, and other inputs typically contribute higher bacteria and organic matter loads. Fecal coliform bacteria and *E. coli* data are shown in Figures 5.9 through 5.12. Hunting Camp Creek is listed as impaired due to non-support of the "swimming" designated use (primary contact recreation) based on the frequency of high bacteria concentrations. Virginia's fecal coliform bacteria criteria include a calendar month geometric mean concentration of 200 colonies/100ml and a single sample maximum concentration of 400 colonies/100ml (9VAC 25-260-170). Virginia's *E. coli* criteria include a calendar month geometric mean concentration of 126 colonies/100 ml and a single sample maximum concentration of 235 colonies/100ml.

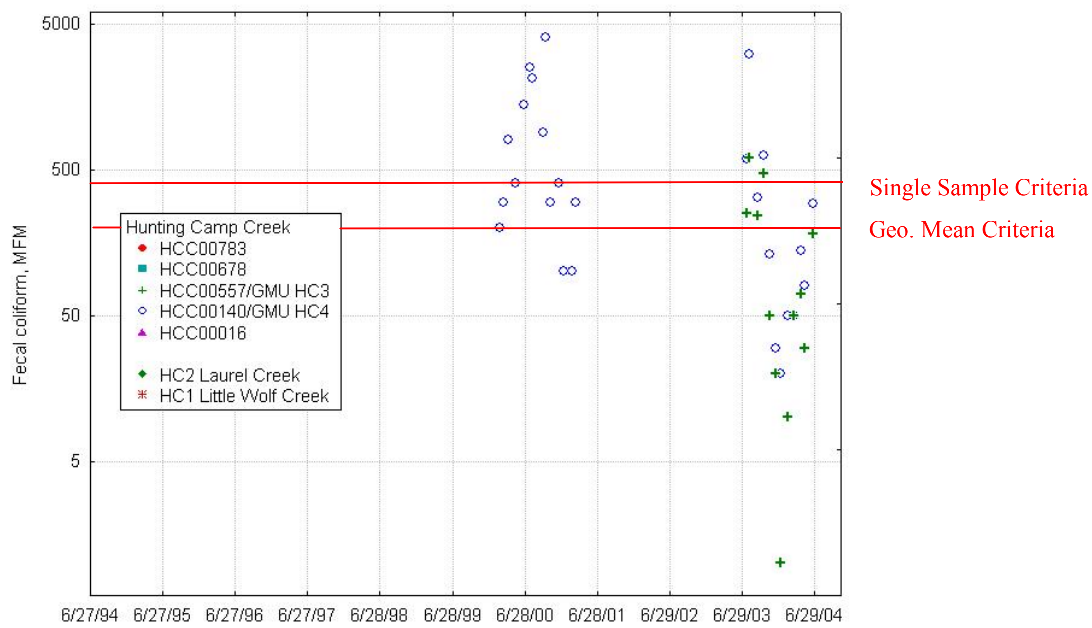

Figure 5.9 Time-series fecal coliform bacteria concentrations (period of record)

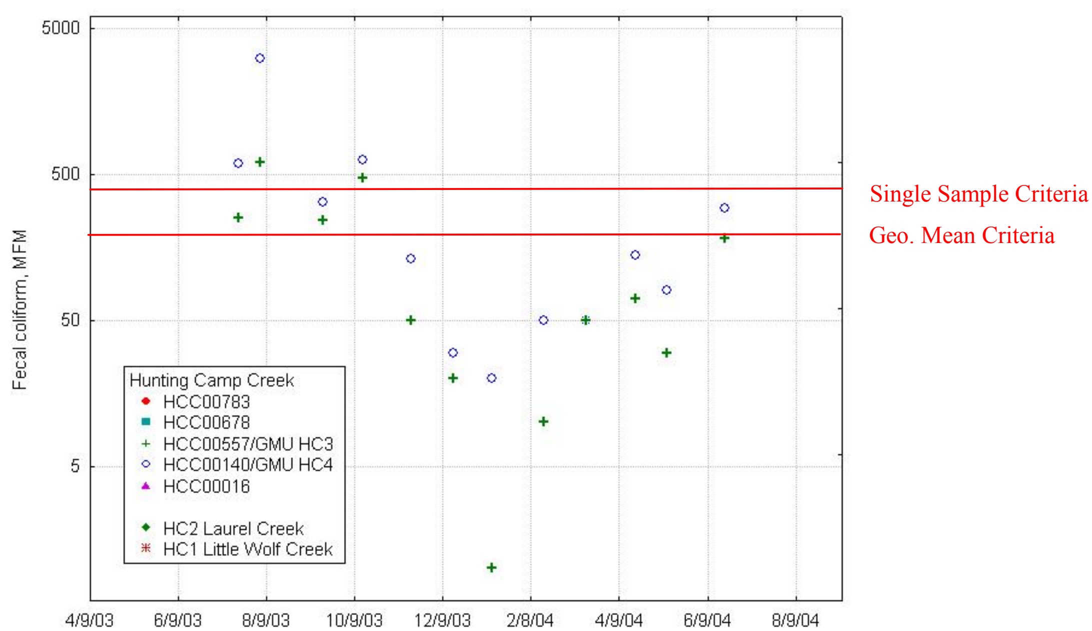

Figure 5.10 Time-series fecal coliform bacteria concentrations (2003-2004)

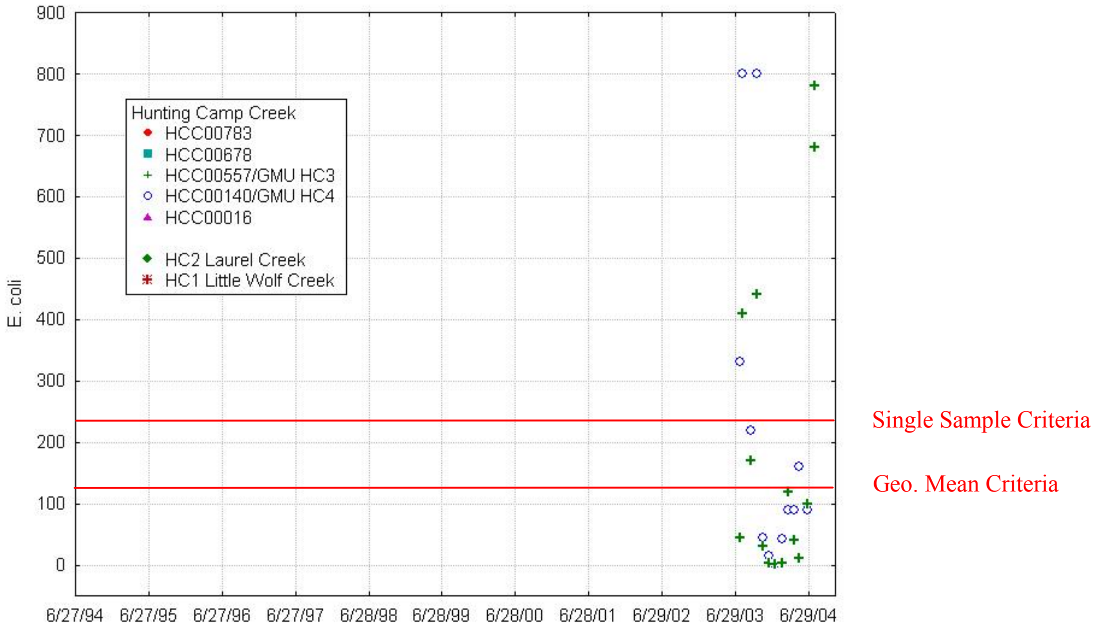

Figure 5.11 Time-series *E. coli* concentrations (period of record)

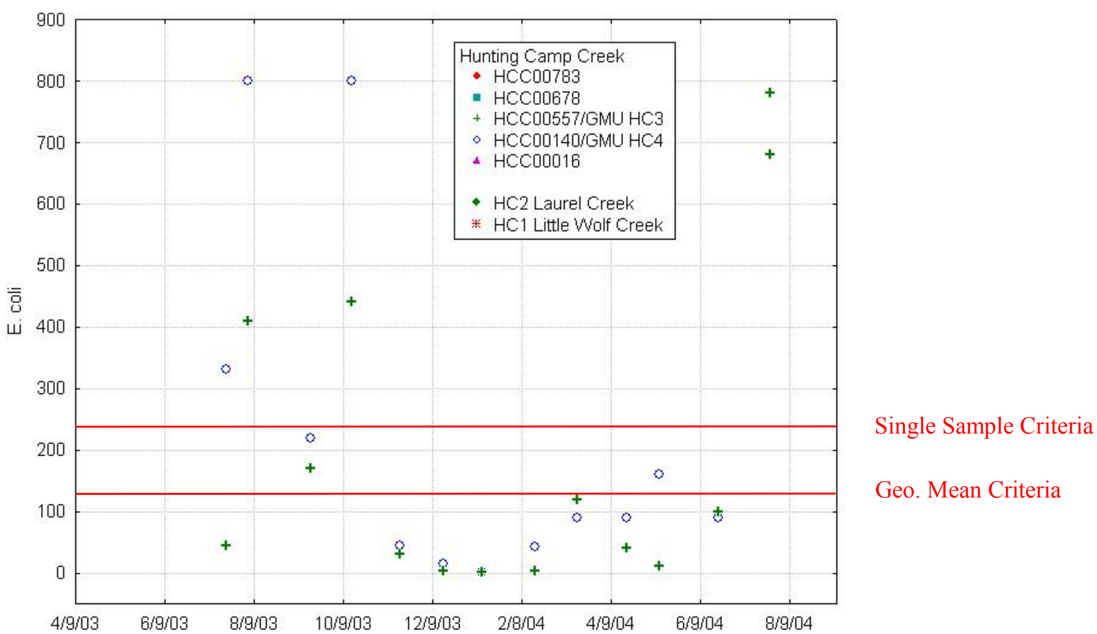

Figure 5.12 Time-series *E. coli* concentrations (2003-2004)

Although high bacteria concentrations were observed, BOD5 levels were relatively low and DO measurements were adequate to support aquatic life. Organic inputs may be causing localized habitat impacts due to the accumulation of organic matter, although there is no specific data available to determine if this is occurring. Habitat data collected on Hunting Camp Creek are further discussed in Section 5.4.6. Based on these data, organic matter is not considered a possible stressor, given the information available.

5.4.5 Nutrients - eliminated stressor

Excess nutrient concentrations have been documented to have numerous secondary negative impacts on aquatic biota. In general, nutrient over-enrichment can lead to eutrophication or hypereutrophication of a waterbody. Under these conditions, algal blooms become more common, sedimentation increases, and there is a pronounced shift in trophic state. Negative consequences can include increased turbidity, a decreased photic zone, local extinction of specialized or intolerant aquatic flora, high pH levels, low dissolved oxygen, and decreased substrate stability.

Excess nutrients in streams are often caused by runoff from agriculture and livestock, direct or "straight pipe" additions, suburban lawns, acid rain, golf courses, and leaky or inefficient septic systems. Although the effects of excessive nutrient concentrations have been documented in various stream assessments, lakes and other larger waterbodies (e.g. Chesapeake Bay), are particularly susceptible to nutrient enrichment due to lower flushing rates and other factors.

Phosphorus

Phosphorus is generally present in waters and wastewaters in different species of soluble (dissolved) and insoluble (particulate or suspended) phosphates, including inorganic (ortho- and condensed) phosphates and organic phosphates. Major sources of phosphorus include detergents, fertilizers, domestic sewage, and agricultural runoff.

Total phosphorus and ortho-phosphate data are presented in Figures 5.13 through 5.15. The majority of the total phosphorus measurements were less than or equal to 0.2mg/L, which is the upper limit of the VADEQ 305(b) assessment criteria. The highest measurements were recorded at stations 9-HCC001.40/HC4, 9-HCC005.57/HC3, HC1, and HC2. Ortho-phosphate was only measured at station 9-HCC001.40. Although there were a few high total phosphorus and ortho-phosphate measurements recorded, phosphorus levels do not appear to be consistently elevated and DO concentrations were acceptable at all stations. Therefore, phosphorus was not considered to be a possible benthic stressor.

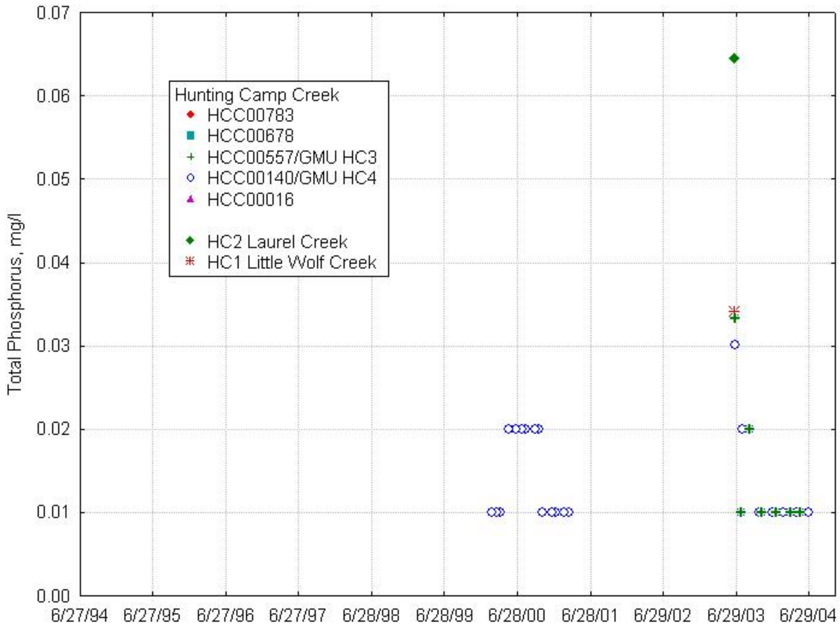

Figure 5.13 Time-series total phosphorus concentrations (period of record)

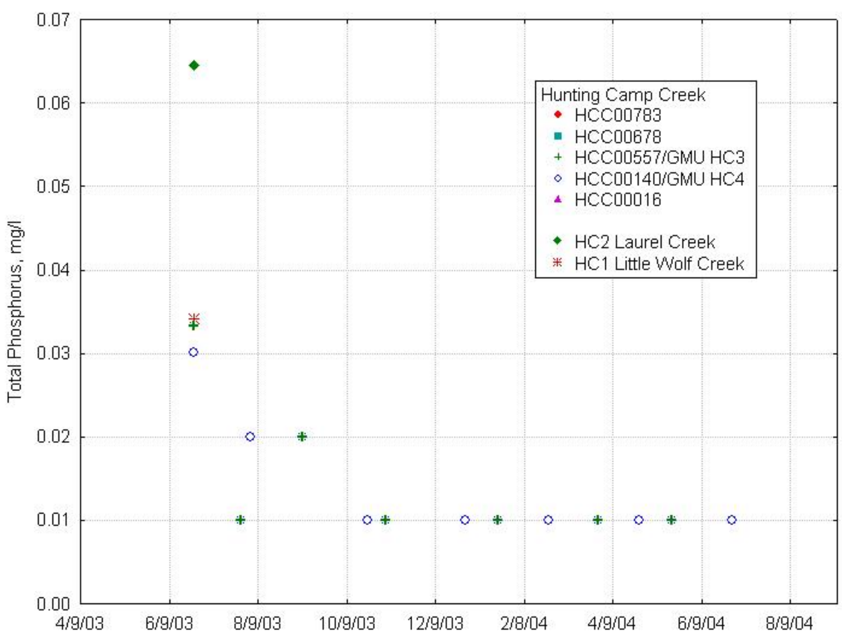

Figure 5.14 Time-series total phosphorus concentrations (2003-2004)

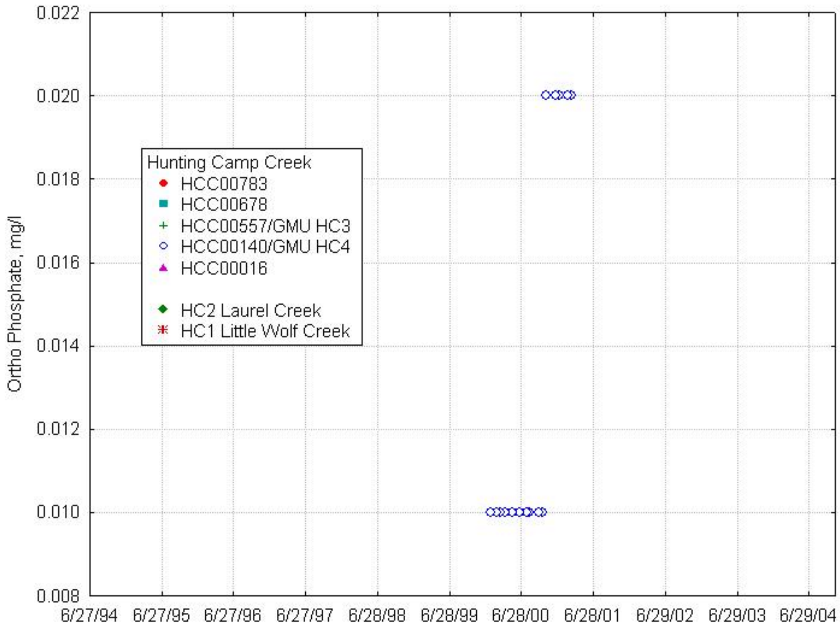

Figure 5.15 Time-series ortho-phosphate concentrations

Nitrogen

Major sources of nitrogen include municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes, runoff from fertilized agricultural fields and lawns, and discharges from car exhausts. Nitrate and nitrite data are presented in Figures 5.16 through 5.20. These data show a similar pattern as compared to the phosphorus data, with the highest concentrations recorded in June 2003. Laurel Creek and Little Wolf Creek had the highest nitrate values during this sampling and VADEQ station 9-HCC001.40 recorded the highest nitrate+nitrite value. Nitrogen levels may have been higher during this time due to increased runoff levels that may have coincided with stream sampling, and/or other factors. In general, these data suggest acceptable nitrogen levels, which may increase during runoff events that can contribute high nutrient loads from urban and agricultural lands in the watershed. These acute nitrogen concentration are likely not sufficient to cause an impairment to the benthic community. Ammonia data are discussed in Section 5.4.7.

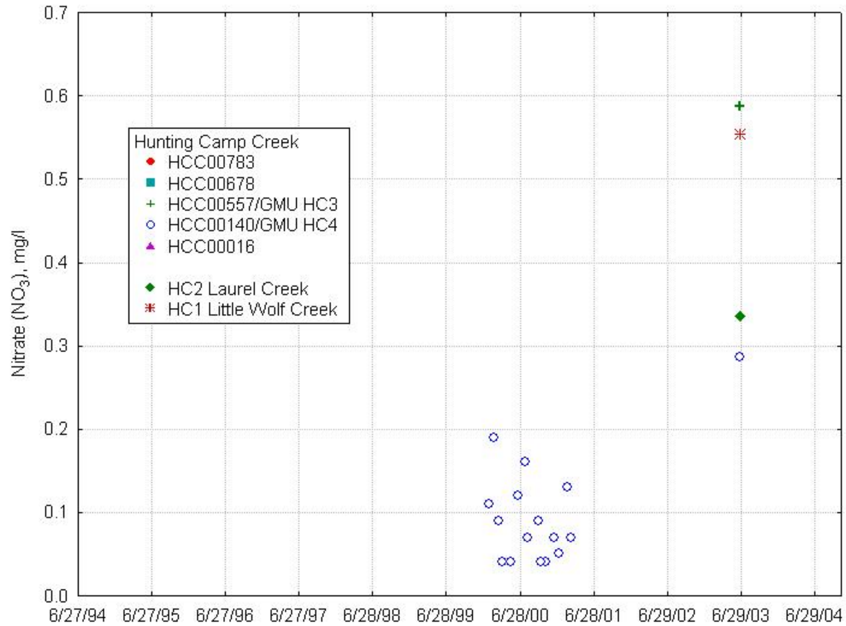

Figure 5.16 Time-series nitrate values (period of record)

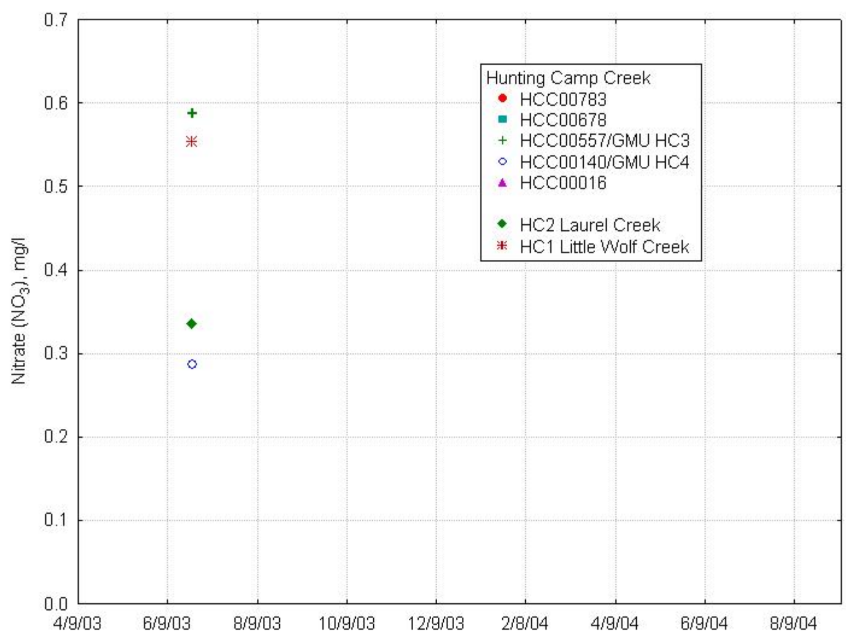

Figure 5.17 Time-series nitrate values (2003-2004)

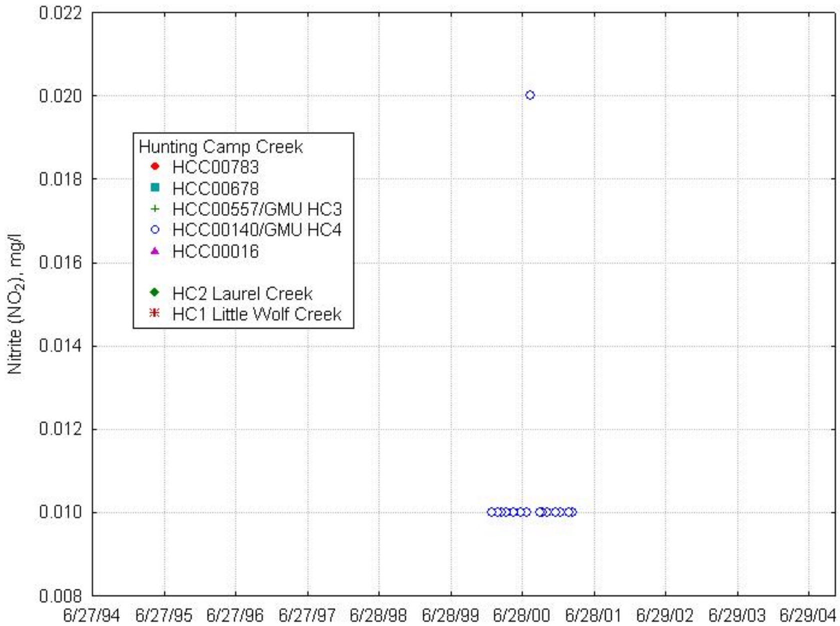

Figure 5.18 Time-series nitrite values

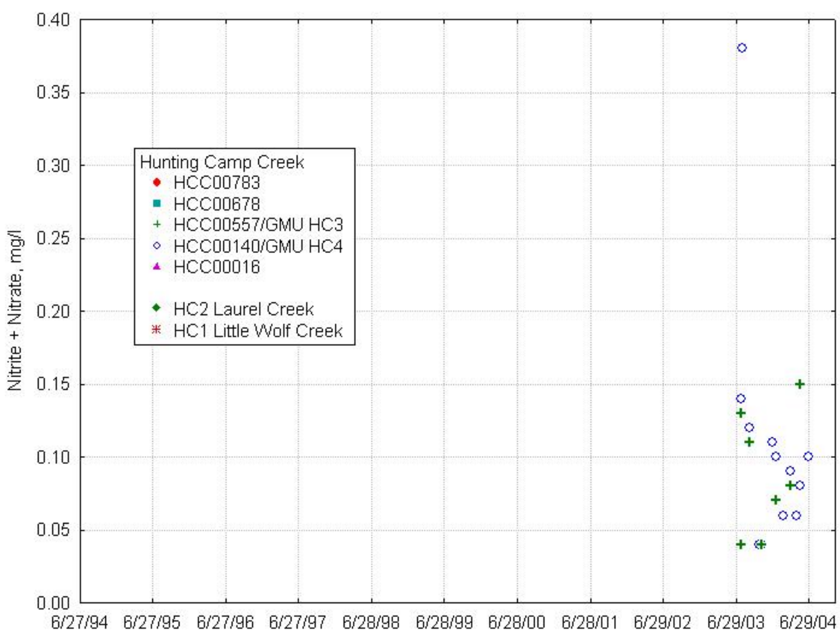

Figure 5.19 Time-series nitrate+nitrite values (period of record)

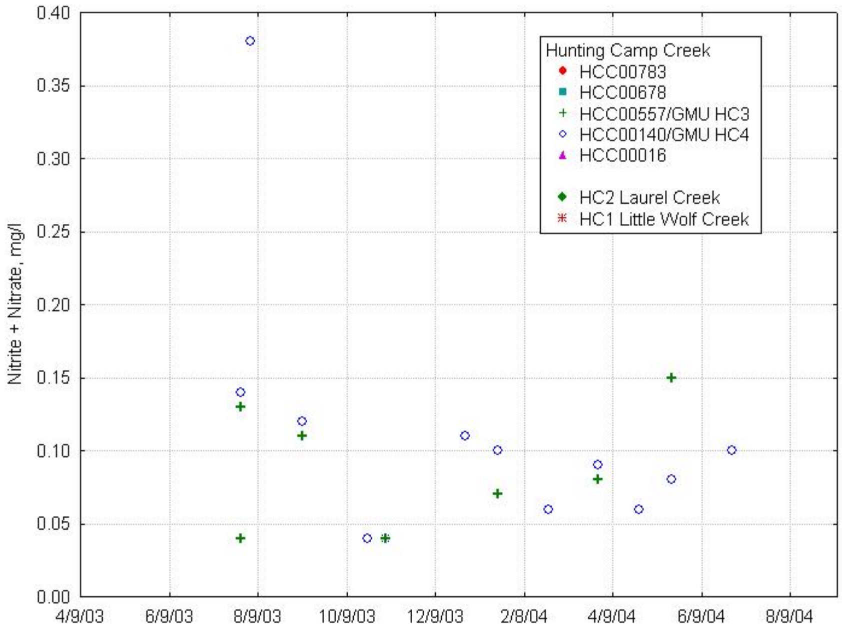

Figure 5.20 Time-series nitrate+nitrite values (2003-2004)

5.4.6 Sedimentation - most probable stressor

Excessive sedimentation from anthropogenic sources is a common problem that can impact the stream biota in a number of ways. Deposited sediments reduce habitat complexity by filling pools, critical riffle areas, and the interstitial spaces used by aquatic invertebrates. Substrate size is a particularly important factor that influences the abundance and distribution of aquatic insects. Sediment particles at high concentrations can directly affect aquatic invertebrates by clogging gill surfaces and lowering respiration capacity. Suspended sediment also increases turbidity in the water column which can affect the feeding efficiency of visual predators and filter feeders. In addition, pollutants, such as phosphorus, adsorb to sediment particles and are transported to streams through erosion processes.

<u>Habitat Alteration and Riparian Vegetation</u>

Sedimentation and habitat alteration are often directly related. The lack of an adequate riparian buffer along stream sections is often considered to be a potential factor affecting the benthic community. Minimal riparian vegetation was observed in specific areas during field visits. These riparian areas perform many functions that are critical to the ecology of the streams that they border. Functional values include: flood detention, bank stabilization, nutrient cycling, wildlife habitat, and canopy shading which decreases water temperature and increases baseflow through lower evaporation rates.

<u>Total Suspended Solids and Turbidity</u>

Total suspended solids (TSS) and turbidity data are presented in Figures 5.21 through 5.24. In general, TSS and turbidity levels were low, with some higher concentrations shown at VADEQ station 9-HCC001.40. The predominant land use in the Hunting Camp Creek watershed is forest land, which typically contributes low amounts of sediment to the stream during runoff periods. The primary source of sedimentation is likely from agricultural runoff and streambank erosion, as discussed in the 2002 303(d) Fact Sheet for Hunting Camp Creek. The stream corridor is characterized by denuded stream banks with little riparian vegetation in agricultural areas, primarily due to livestock grazing.

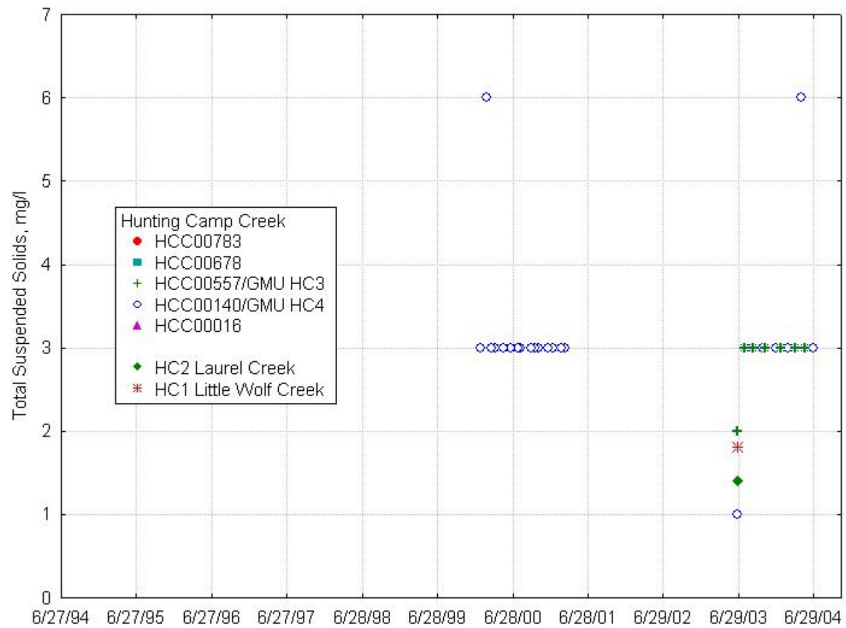

Figure 5.21 Time-series TSS values (period of record)

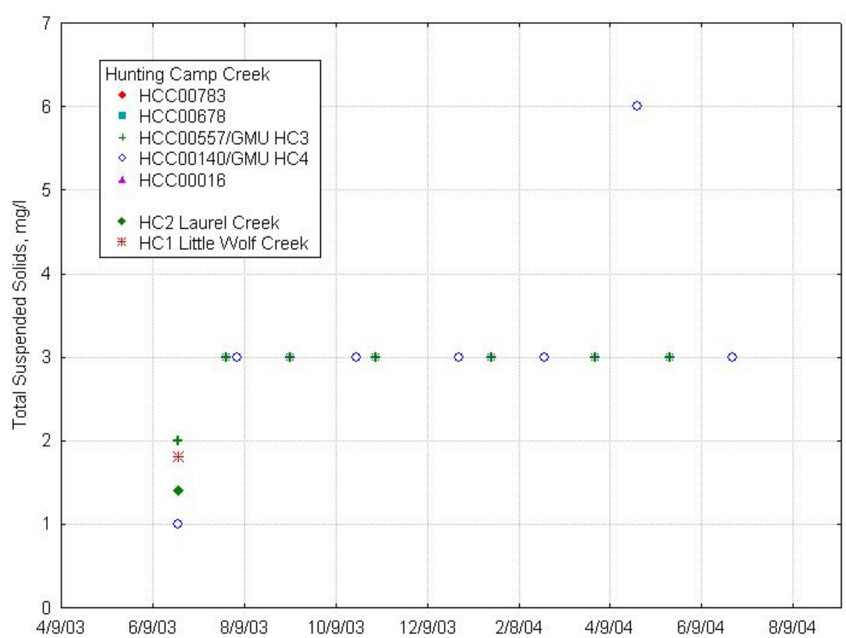

Figure 5.22 Time-series TSS values (2003-2004)

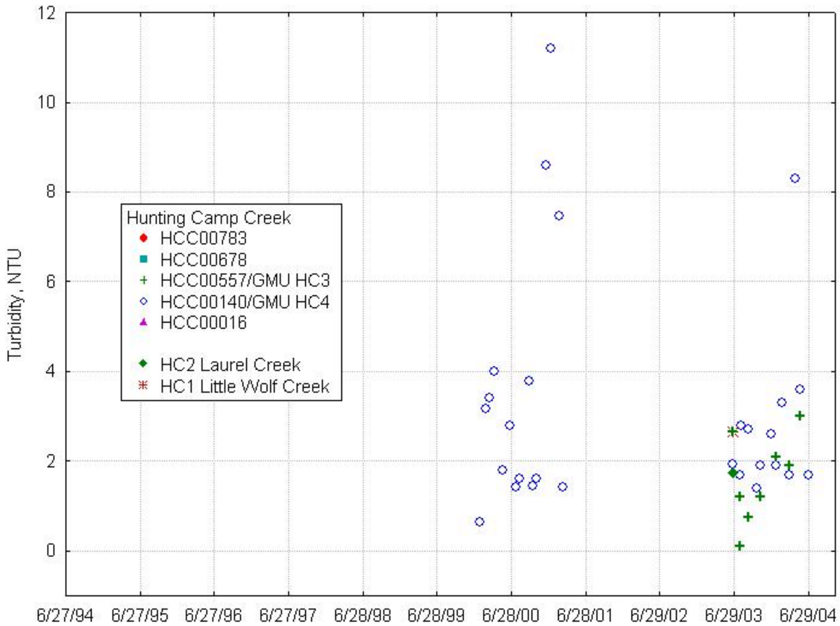

Figure 5.23 Time-series turbidity values (period of record)

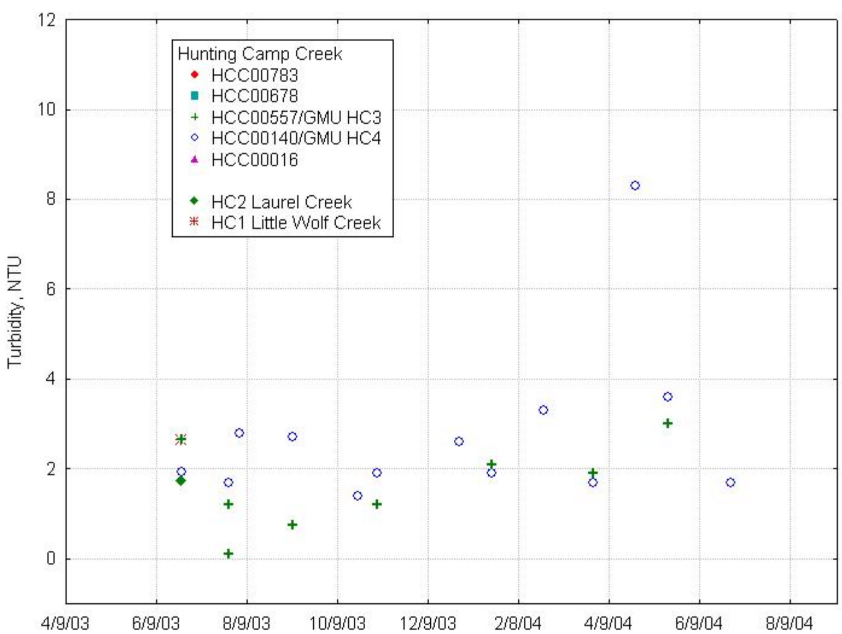

Figure 5.24 Time-series turbidity values (2003-2004)

<u>Rapid Bioassessment Protocol - Habitat Data</u>

Rapid Bioassessment Protocol (RBP) habitat data for Hunting Camp Creek and reference streams are shown in Table 5.6. These data are also presented graphically in Figures 5.25 through 5.37 (Hunting Camp Creek data shown in blue). These data were used to examine possible sedimentation and other habitat impacts to the benthic community, along with the TSS and turbidity data discussed above. All habitat scores were evaluated and rated by observation (0-20, with higher scores being better). The following parameters were measured in the habitat assessment for Hunting Camp Creek:

- Instream cover (for fish)
- Epifaunal substrate – relative quantity and variety of natural structures in the stream for spawning and nursery functions of aquatic macrofauna
- Embeddedness – extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom
- Velocity/depth regimes
- Channel alteration – measure of large-scale changes in the shape of the stream channel
- Sediment deposition – amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition
- Frequency of riffles
- Channel flow status – degree to which the channel is filled with water
- Condition of banks – whether the stream banks are eroded (or have the potential for erosion)
- Bank vegetative protection – the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone
- Grazing or other bank disruptive pressure
- Riparian vegetation zone width – width of natural vegetation from the edge of the stream bank out through the riparian zone

Habitat parameters which provide information on possible sedimentation problems include epifaunal substrate, embeddedness, sediment deposition, and vegetative protection. Habitat assessments for Hunting Camp Creek included scores in the “fair” or “poor” range indicating disturbed habitat conditions, possibly caused by excessive sedimentation. Habitat assessments are generally a better gauge of sedimentation problems than TSS and turbidity measurements that may be elevated only after storm events. These data, however, show mixed results with low and high habitat scores. Visual observations noted by VADEQ field personnel indicate a high potential for land surface and streambank erosion in agricultural portions of the watershed.

Table 5.6 Rapid Bioassessment Protocol - Habitat Data

Station	Stream	Date	Instream Cover	Epifaunal Substrate	Embeddedness	Velocity/Depth Regimes	Channel Alteration	Sediment Deposition	Frequency of Riffles	Channel Flow Status	Bank Stability	Bank Vegetative Protection	Grazing or Other Disruptive Pressure	Riparian Zone Width	Total
9-HCC001.40	Hunting Camp Creek	10/4/1994	13	7	17	7	17	13	11	7	8	9	7	3	119
9-CVR002.47	Cove Creek	10/24/1994	13	14	8	17	18	9	10	18	9	17	3	3	139
9-HCC001.40	Hunting Camp Creek	5/24/1996	18	17	11	15	15	14	17	18	11	14	7	11	168
9-HCC001.40	Hunting Camp Creek	10/25/1996	17	16	11	10	14	14	17	18	12	18	7	8	162
9-WFC034.82	Wolf Creek	10/25/1996	19	18	12	15	17	17	18	19	16	19	12	15	197
9-HCC001.40	Hunting Camp Creek	5/19/1998	17	17	12	10	13	7	16	19	11	17	7	6	152
9-LAC000.92	Laurel Creek	5/19/1998	18	17	9	16	15	7	16	18	17	18	11	8	170
9-HCC001.40	Hunting Camp Creek	11/9/1998	14	9	8	9	13	6	9	9	7	16	7	6	113
9-LAC000.92	Laurel Creek	11/9/1998	18	17	10	13	14	9	16	9	9	16	12	7	150
9-HCC001.40	Hunting Camp Creek	5/12/1999	16	15	14	10	15	9	15	18	9	17	10	9	157
9-LAC000.92	Laurel Creek	5/12/1999	17	17	17	15	15	13	16	18	15	17	15	8	183
9-HCC001.40	Hunting Camp Creek	10/28/1999	15	7	8	8	13	7	7	8	7	15	7	7	109
9-LAC000.92	Laurel Creek	10/28/1999	18	16	9	14	15	9	16	8	12	18	11	10	156
9-HCC007.83	Hunting Camp Creek	11/25/2003	N/A	17	10	10	14	5	18	17	4*	15*	N/A	14*	124
9-HCC000.29	Hunting Camp Creek	11/25/2003	N/A	16	6	18	18	3	16	17	12*	13*	N/A	8*	127
9-HCC001.40	Hunting Camp Creek	11/25/2003	N/A	17	15	15	15	10	13	18	6*	7*	N/A	7*	123
6BMID000.20	Middle Creek	11/17/2003	N/A	14	9	10	15	11	16	18	14*	10*	N/A	13*	130
9-HCC007.83	Hunting Camp Creek	5/26/2004	N/A	15	16	10	15	6	16	17	13*	18*	N/A	18*	144
9-HCC000.29	Hunting Camp Creek	5/26/2004	N/A	16	15	12	15	7	12	17	13*	13*	N/A	8*	128
9-HCC001.40	Hunting Camp Creek	5/25/2004	N/A	11	13	14	17	7	9	17	13*	16*	N/A	4*	121

*Total of left and right bank scores shown

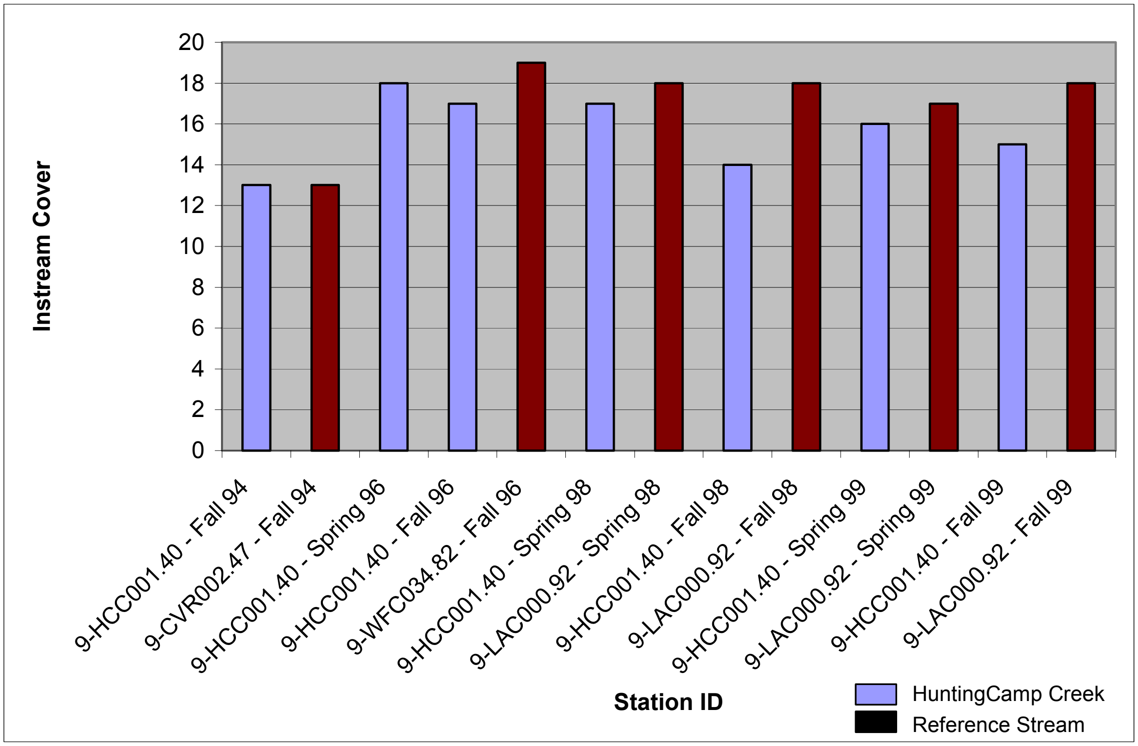

Figure 5.25 Instream cover

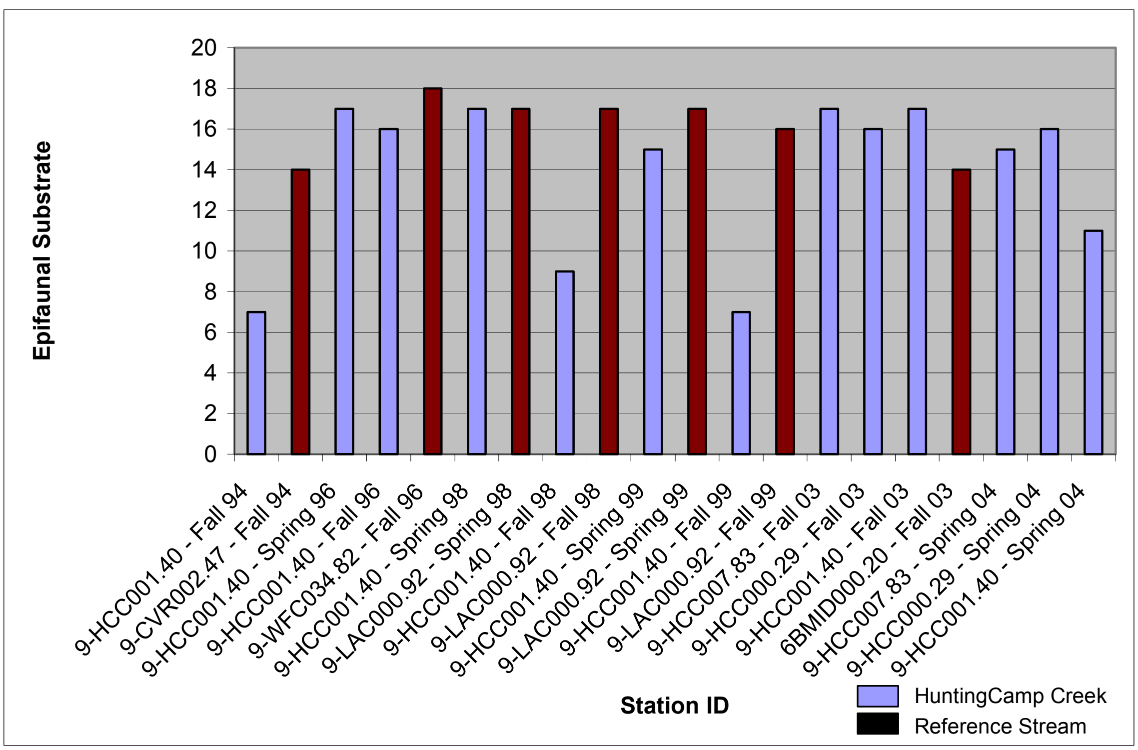

Figure 5.26 Epifaunal substrate

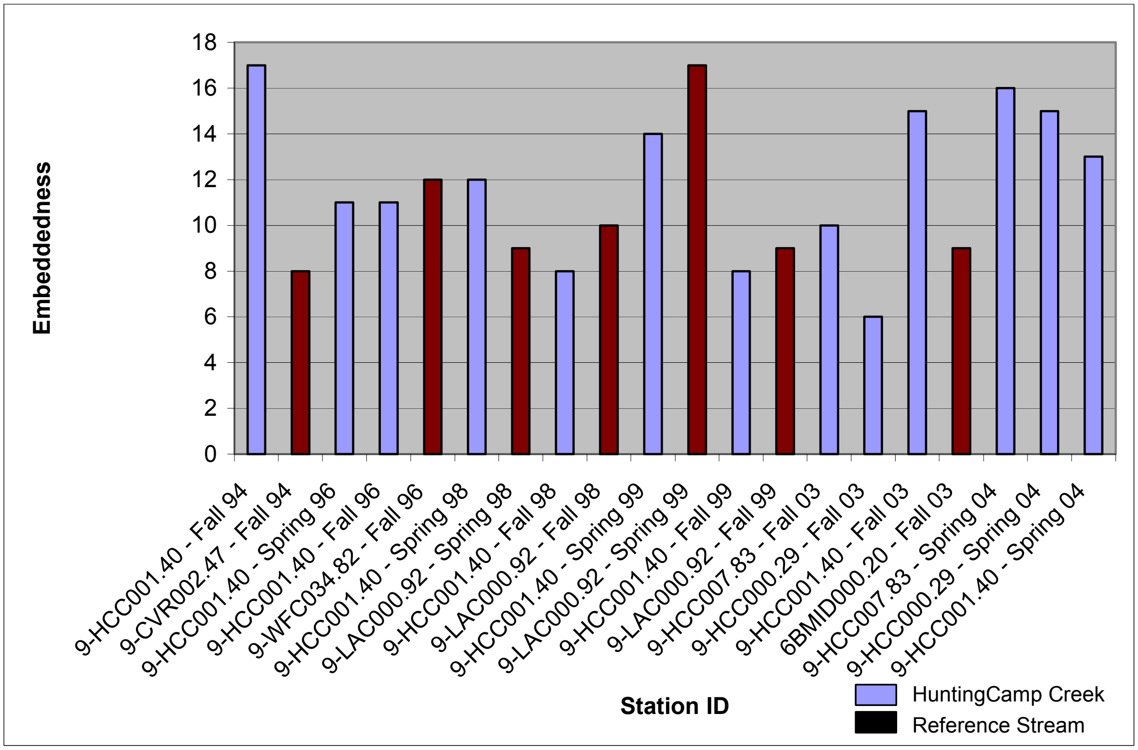

Figure 5.27 Embeddedness

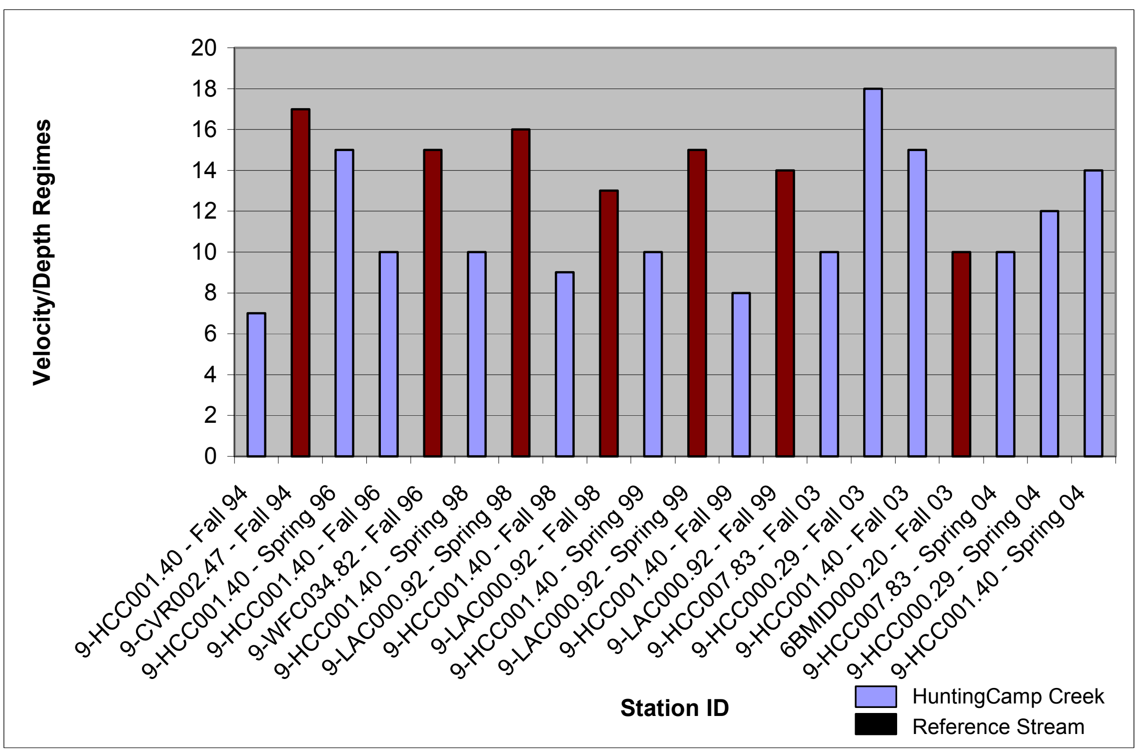

Figure 5.28 Velocity/depth regimes

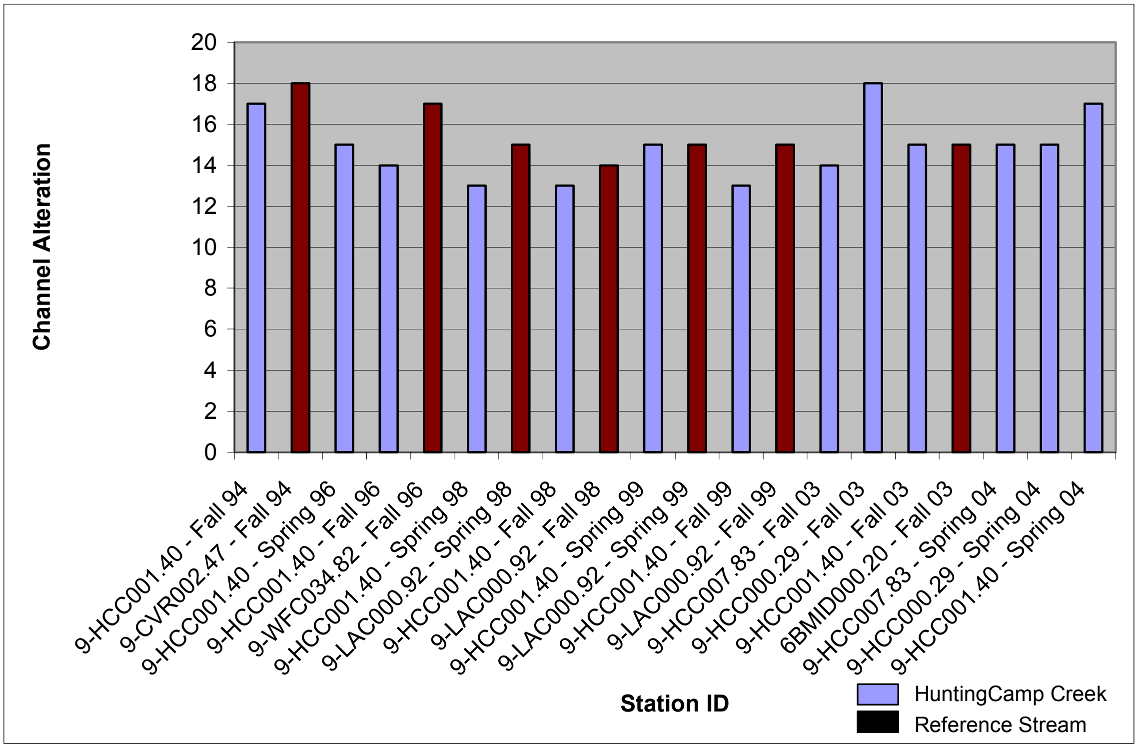

Figure 5.29 Channel alteration

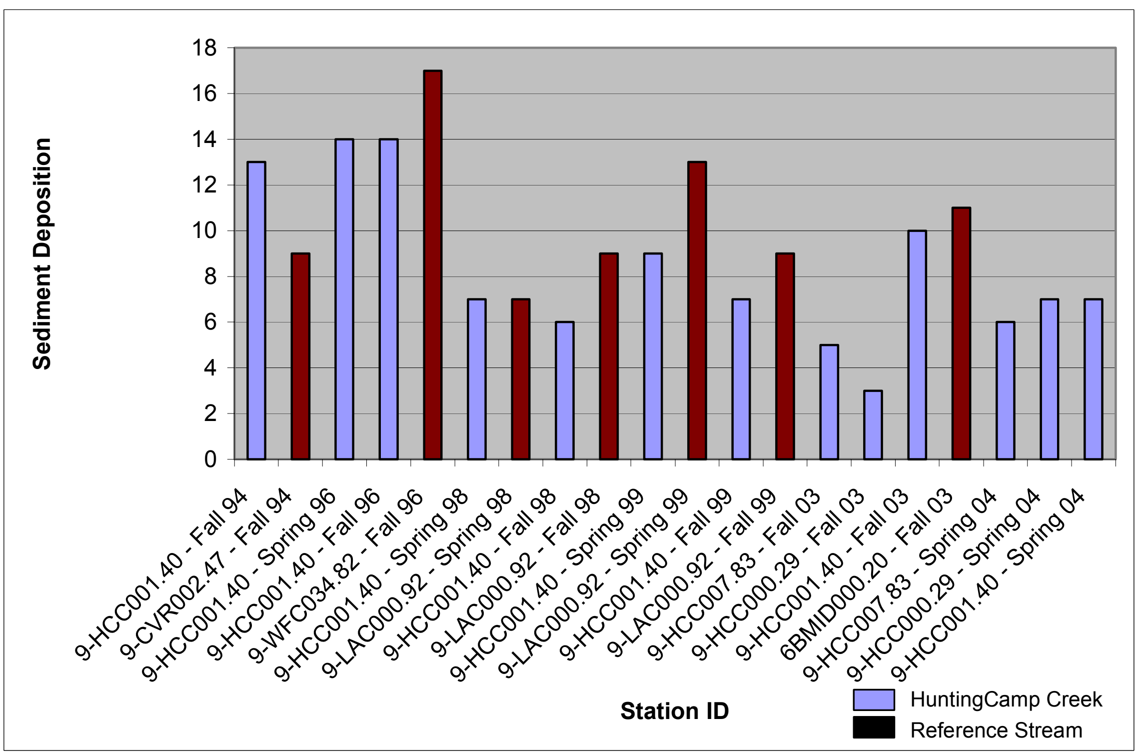

Figure 5.30 Sediment deposition

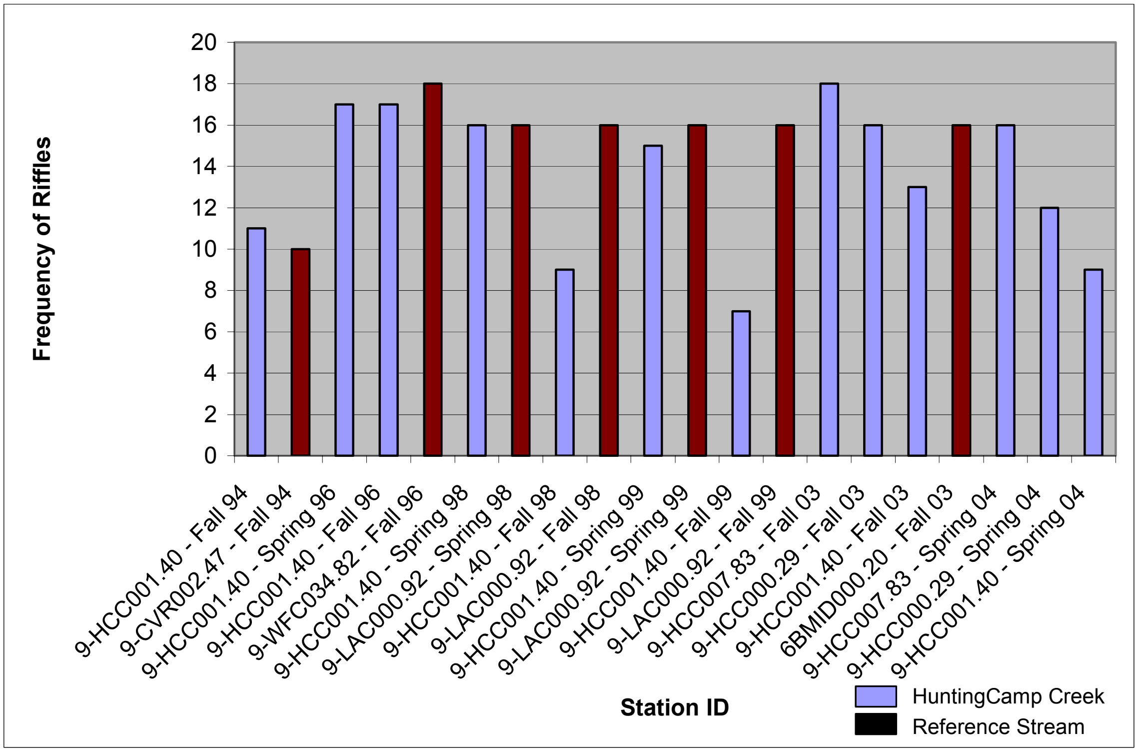

Figure 5.31 Frequency of riffles

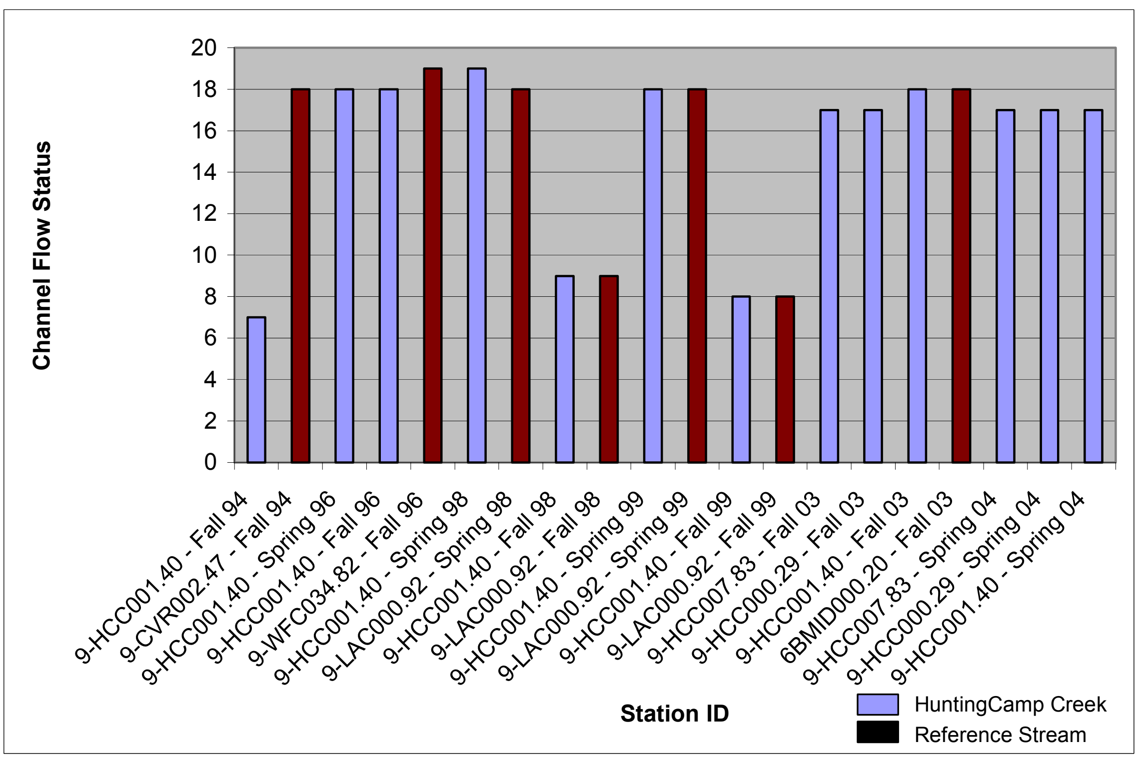

Figure 5.32 Channel flow status

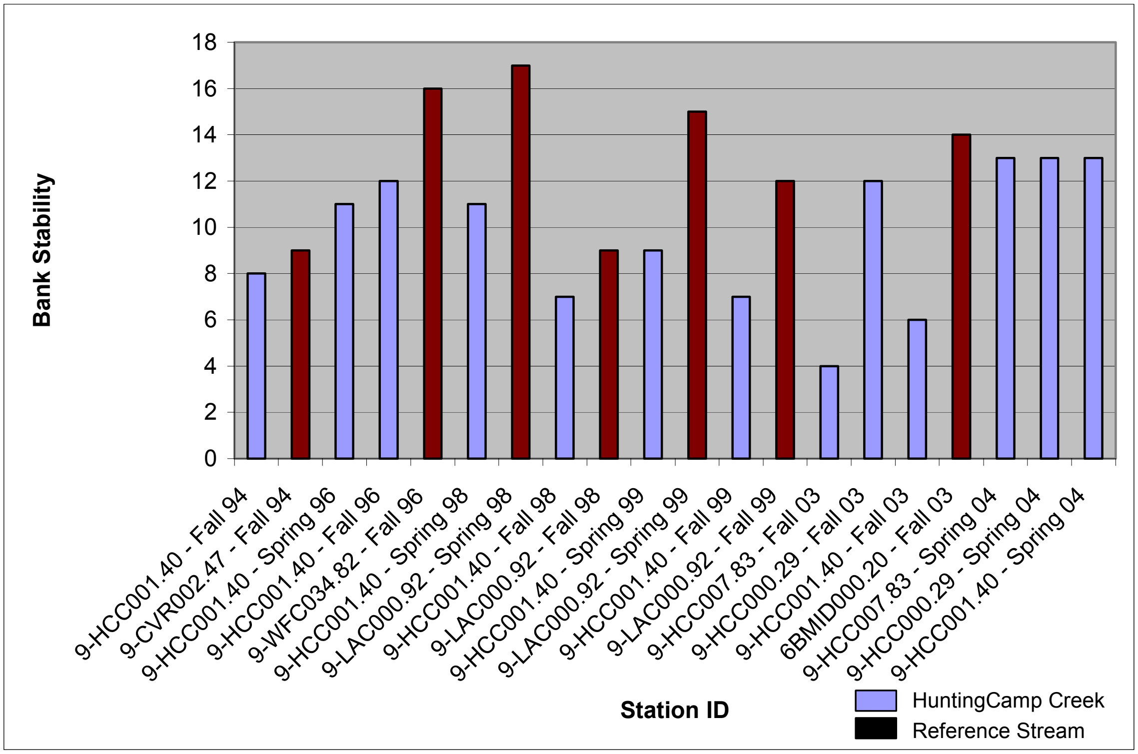

Figure 5.33 Bank stability

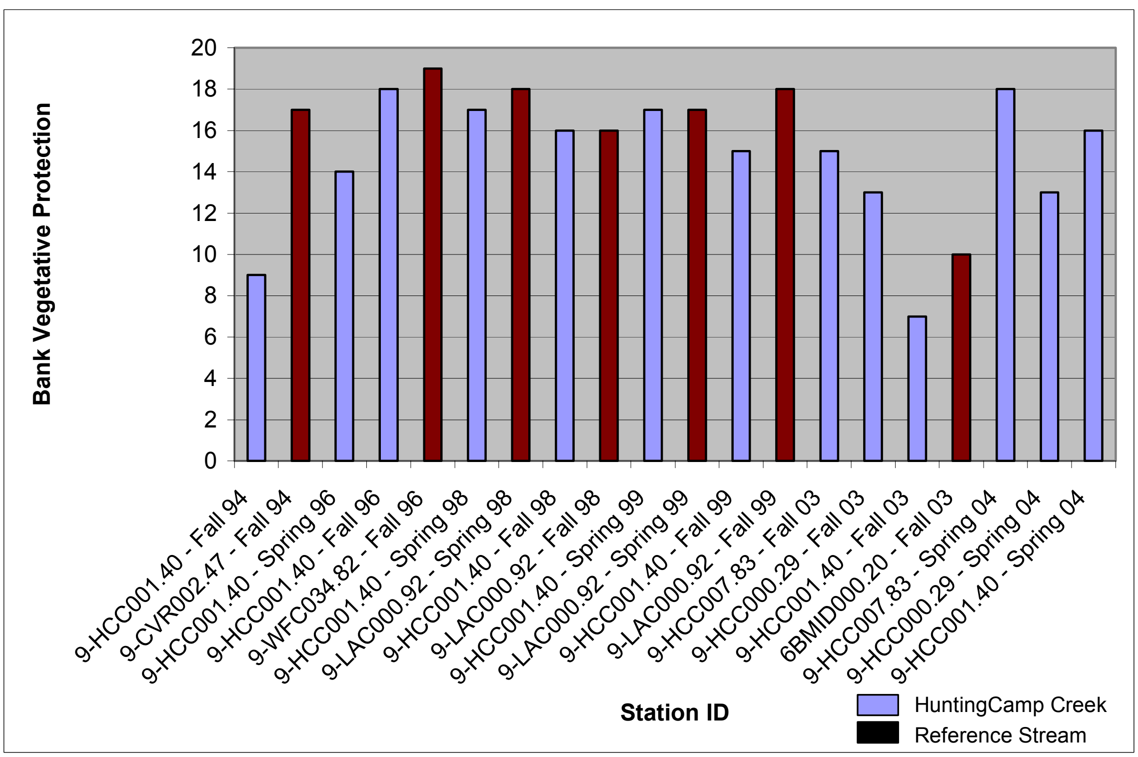

Figure 5.34 Bank vegetative protection

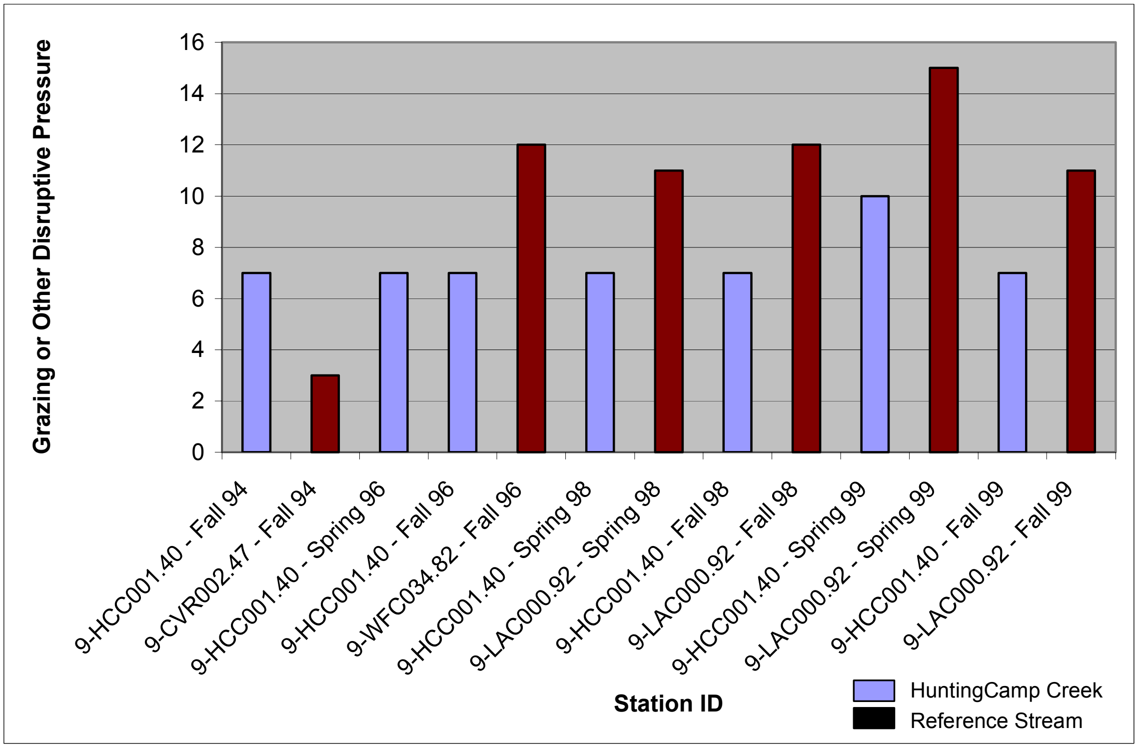

Figure 5.35 Grazing or other disruptive pressure

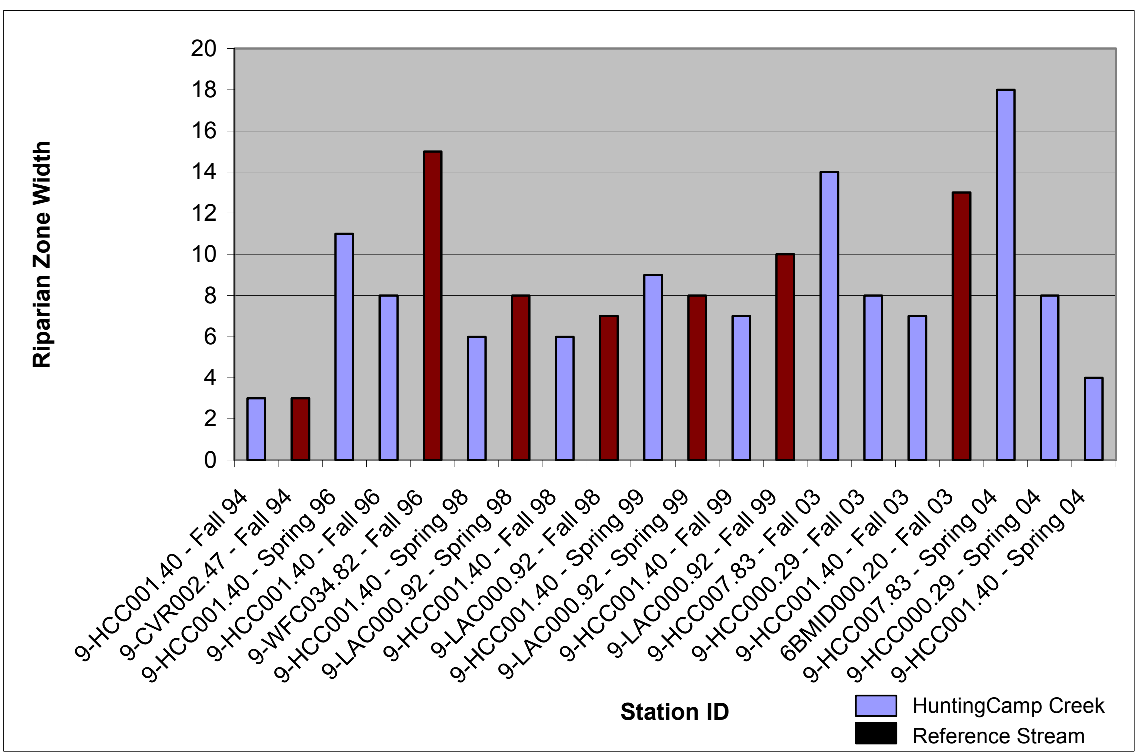

Figure 5.36 Riparian zone width

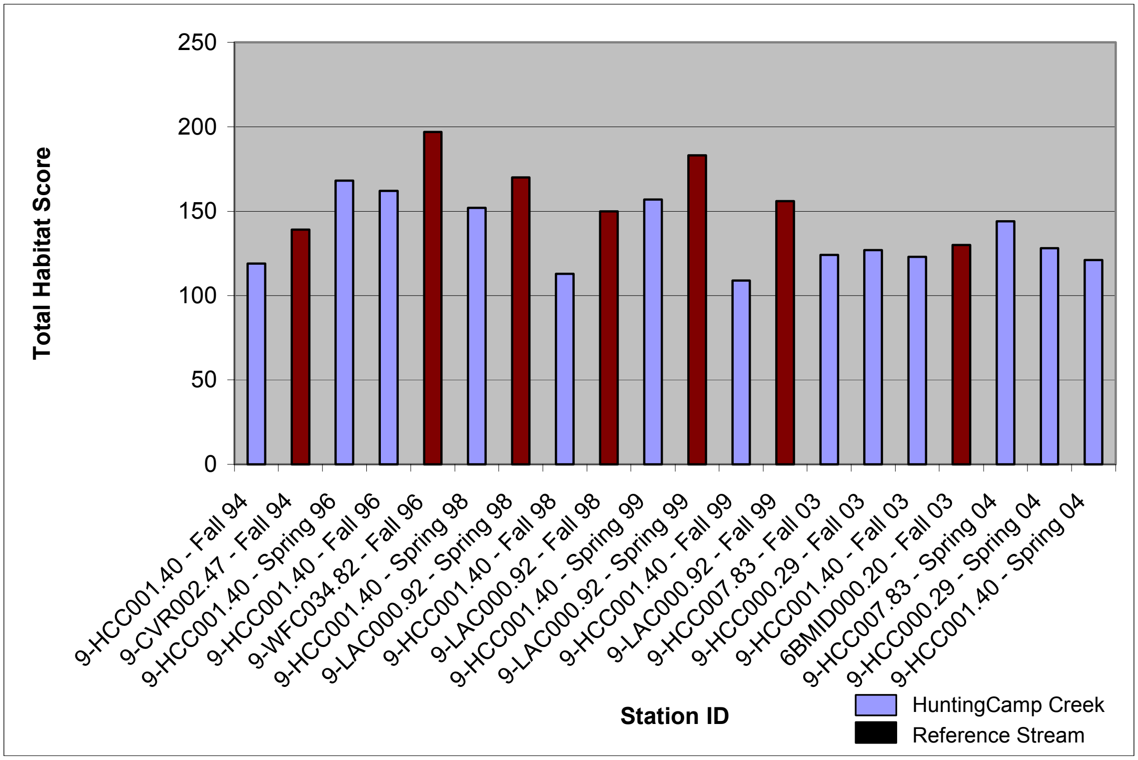

Figure 5.37 Total habitat scores

<u>DGIF Fish Survey – Habitat Results</u>

DGIF conducted a fish survey on Hunting Camp Creek in 1999. A total of 15 species of warm water fishes were found in the survey. A habitat assessment was also conducted using Ohio EPA assessment methods and the results indicated normal levels of sediment in the stream at the sampling locations, with bedrock as the main substrate.

Based the RBP habitat assessment results and field observations by VADEQ and GMU personnel, excessive sedimentation is considered to be a stressor to the benthic community

Note that sediment reductions in the Hunting Camp Creek watershed will result in the reduction in nutrients, organic matter, and other pollutants that may be causing water quality and biological problems. Best Management Practices (BMPs) that are typically used to control sediment also help reduce these other pollutants.

5.4.7 Toxics - eliminated stressor

Toxic pollutants in the water column and sediment can result in acute and chronic effects on aquatic organisms. Increased mortality rates, reduced growth and fecundity, respiratory problems, tumors, deformities, and other consequences have been documented in toxicity studies of aquatic organisms. Degraded water quality conditions and other environmental stressors can lead to higher rates of incidence of these problems. Most often, toxic pollutants found in high concentrations in freshwater are there due to anthropogenic activities.

Toxic Pollutants - Surface Water

Virginia's Water Quality Standards list acute and chronic criteria for surface waters (9 VAC 25-260-140). These numeric criteria were developed for metals, pesticides, and other toxic chemicals, which can cause acute and chronic toxicity effects on aquatic life and human health. Available water quality data were compared to these criteria to determine possible effects on aquatic life. Water column samples were collected on 8/19/2003 at VADEQ station 9-HCC001.40 to test for the presence of high metals concentrations. There were no exceedances of established criteria. The majority of these values were at or below laboratory analysis detection limits. High conductivity levels can also indicate high metals loading, pesticide use, and other anthropogenic impacts. Station 9-HCC001.40 recorded the highest conductivity measurements, possibly due to a combination of urban and agricultural runoff (Figures 5.38 and 5.39). This surrogate parameter indicates general water quality degradation, but does not implicate a specific toxic pollutant or impairment cause.

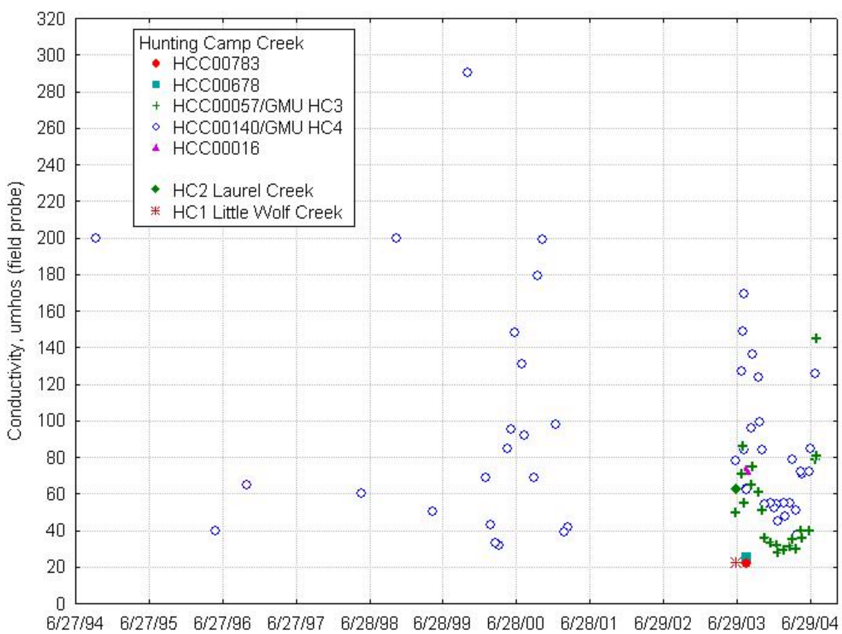

Figure 5.38 Time-series conductivity values (period of record)

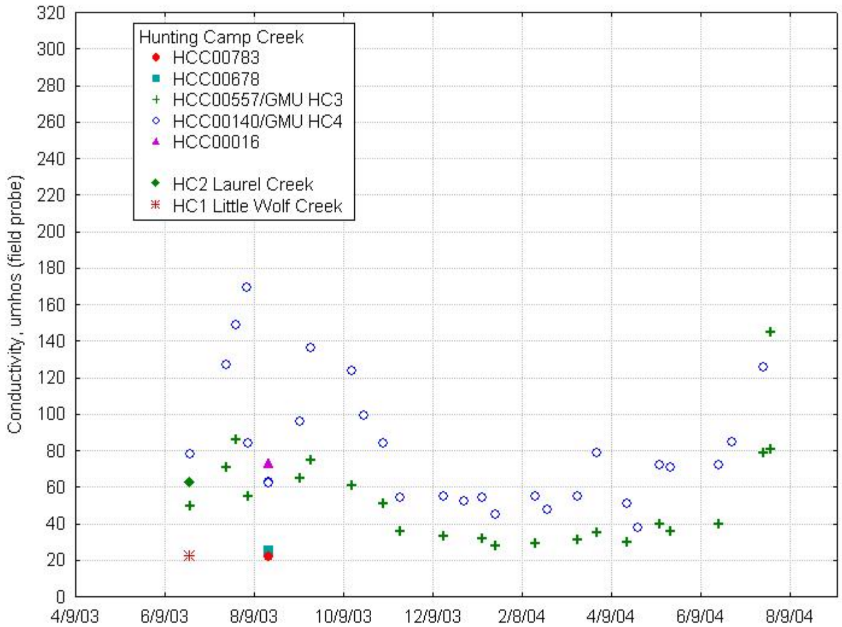

Figure 5.39. Time-series conductivity values (2003-2004)

Ammonia (NH3+NH4) is a critical component of the nitrogen cycle. At high concentrations, ammonia is toxic to aquatic life, depending on pH and temperature levels. In general, the higher the temperature and pH levels, the more toxic ammonia is to aquatic life. Virginia's Water Quality Standards (9 VAC 25-260-155) specify the formulas that are used to calculate the acute and chronic criteria values for ammonia depending on stream type (freshwater or saltwater), temperature, and pH levels, and the expected presence or absence of trout. Ammonia data collected at Hunting Camp Creek monitoring stations were compared to the calculated acute and chronic criteria using pH and temperature data collected at the same time. Ammonia samples were collected on several occasions at two VADEQ stations (9-HCC001.40 and 9-HCC005.57) and on 6/26/2003 at each GMU monitoring station (Figures 5.40 and 5.41). There were no exceedances of acute or chronic ammonia criteria.

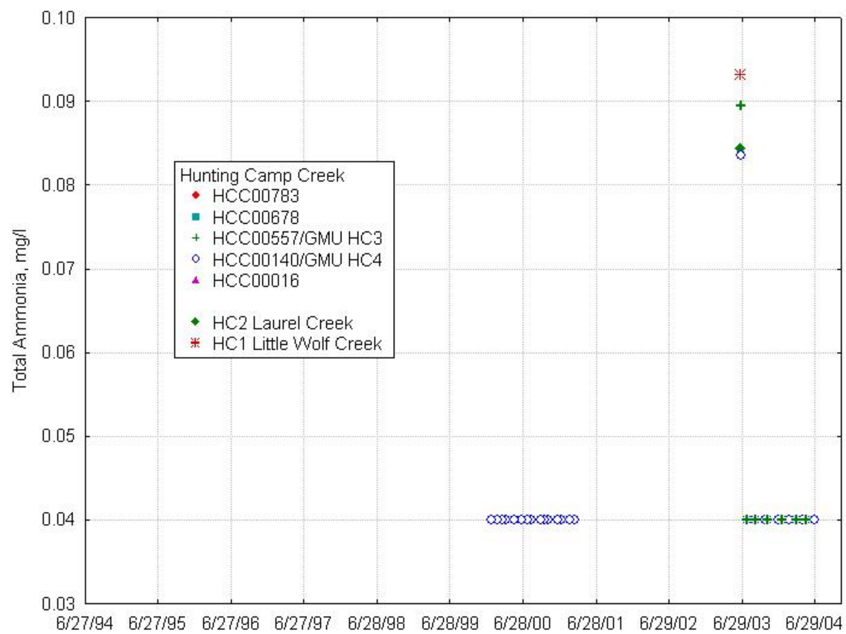

Figure 5.40 Time-series ammonia concentrations (period of record)

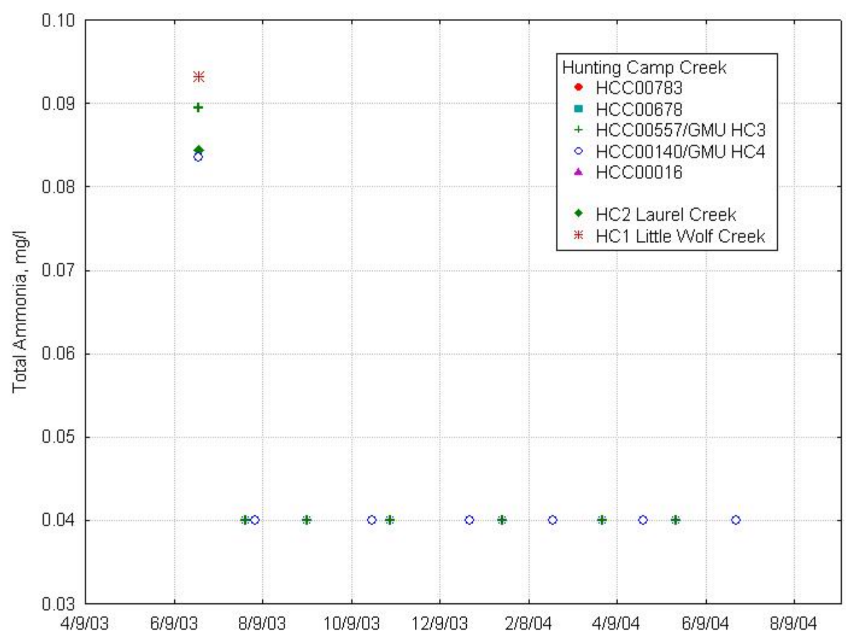

Figure 5.41 Time-series ammonia concentrations (2003-2004)

<u>Toxic Pollutants - Sediment</u>

Virginia's Water Quality Standards and updated 305(b) assessment guidance for sediment parameters were consulted to determine if the available data indicate high levels for metals, pesticides, or other constituents that can cause acute or chronic toxicity effects on aquatic life.

Sediment data were assessed using EPA's Probable Effects Concentration (PEC) thresholds. DEQ currently uses EPA's PEC thresholds to assess water quality conditions and potential toxic effects to aquatic life.

Sediment samples were collected on 8/19/2003 at VADEQ station 9-HCC001.40. The concentration of nickel in sediment (55.5 mg/kg) exceeded the PEC criterion of 48.6 ppb. Note that surface water concentrations of these metals did not exceed the respective water column criteria as discussed above.

EPA Toxicity Testing - acute/chronic toxicity results

A chronic toxicity study was conducted by EPA Region III using fathead minnows (*Pimephales promelas*) and *Ceriodaphnia dubia* (USEPA 2004). The study was conducted on ambient water samples collected at DEQ station 9-HCC001.40 during the week of June 7, 2004. Grab samples were collected by VADEQ, packed in ice, and shipped overnight to EPA's Region III Freshwater Biology Team. The survival/growth of fathead minnows (*Pimephales promelas*) and the survival/reproduction of *Ceriodaphnia dubia* were measured using standard methods. Results pending.

Review of Benthic Taxa Data and Water Quality Implications

Biomonitoring results for Taxa Richness and EPTI metrics are presented in Figures 5.42 and 5.43 for Hunting Camp Creek and corresponding reference streams. USFS biomonitoring results (selected metrics) are presented in Figure 5.44.

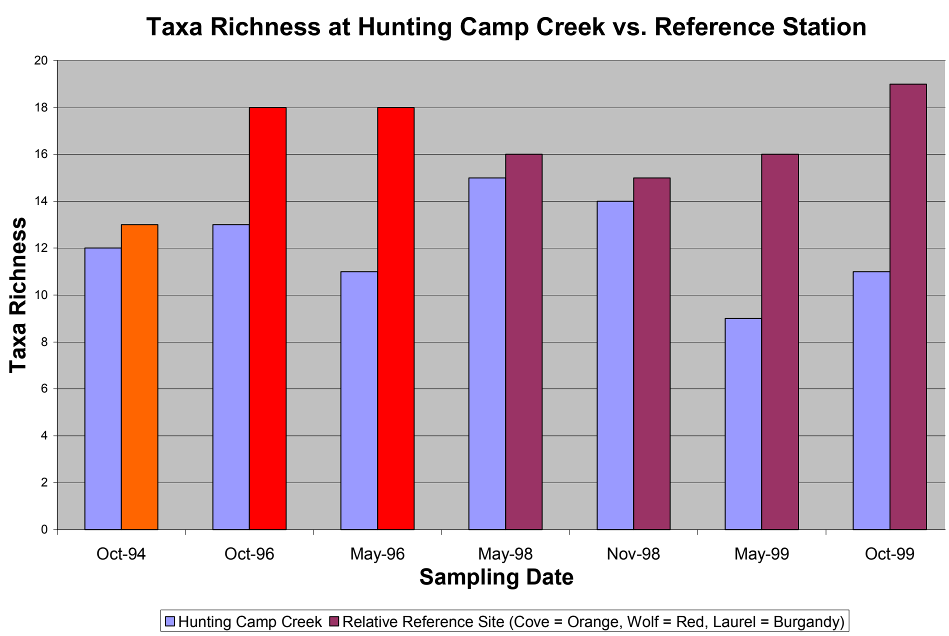

Figure 5.42 Taxa Richness results from DEQ biomonitoring (RBP II)

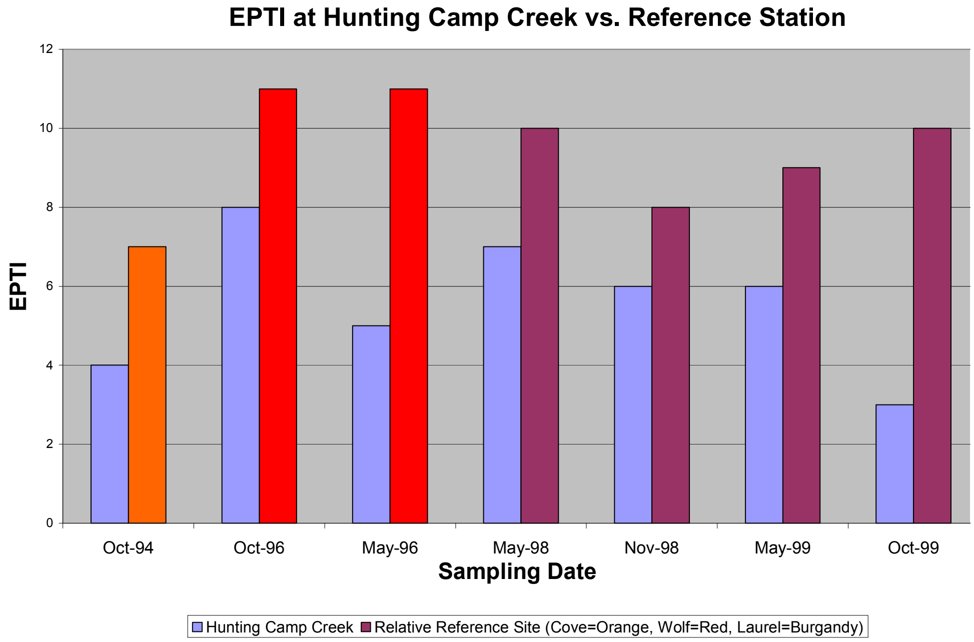

Figure 5.43 EPTI results from DEQ biomonitoring (RBP II)

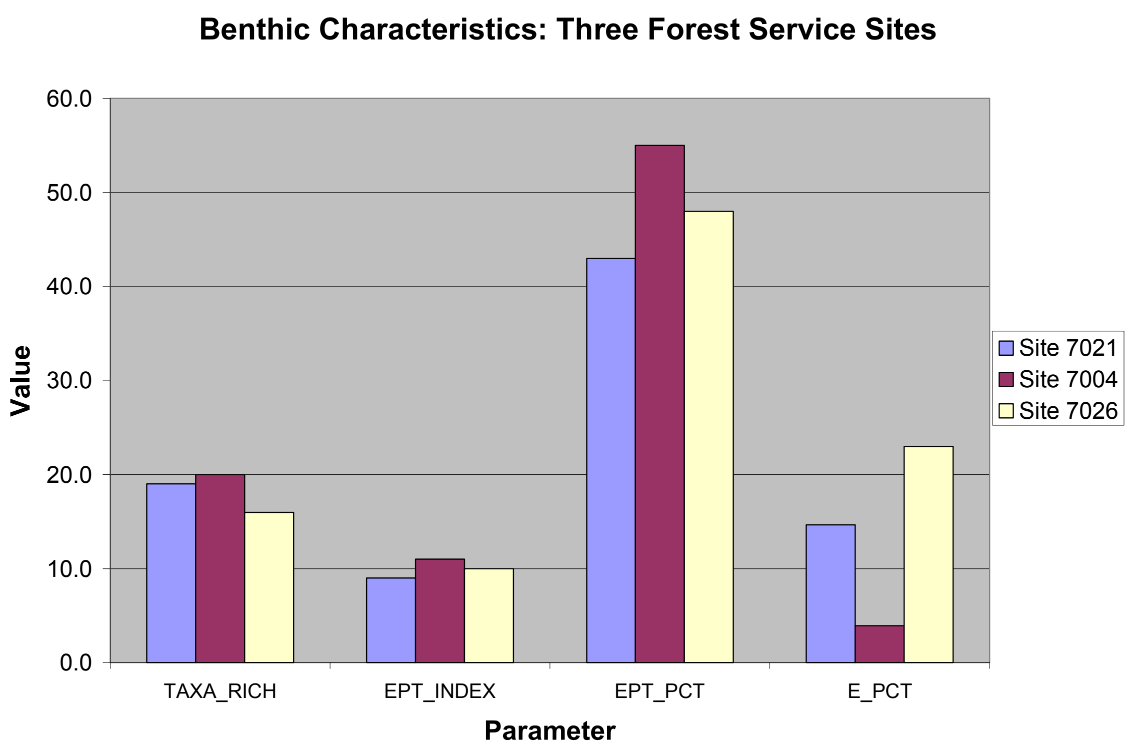

Figure 5.44 USFS biomonitoring results

The largest differences in Taxa Richness and EPTI scores are shown for the most recent VADEQ biomonitoring sampling event presented in these graphs (10/99). These data correspond with the poor habitat measurements shown for Hunting Camp Creek during the same time period. Chironomids and hydropsychid caddisflies were generally the most dominant taxa groups in the benthic samples collected on Hunting Camp Creek. These organisms commonly indicate excessive sedimentation and corresponding habitat problems.

5.5 Stressor Conclusions

Based on the above analysis, it is hypothesized that excessive sedimentation is primarily responsible for the benthic impairment in Hunting Camp Creek. Nutrient levels do not appear to have caused negative impacts to DO and pH conditions; therefore, nutrient (phosphorus) reductions are not required. Sediment samples collected at VADEQ station 9-HCC001.40 indicated an exceedance of EPA's PEC threshold for nickel; however, the surface water concentration was well below the established water quality criterion. All other toxics data were below established criteria levels.

Sediment load reductions should reduce nutrients, organic matter inputs, and other pollutants that may be causing water quality and biological problems. Best Management Practices (BMPs) that are typically used to control sediment also help reduce these other pollutants.

SECTION 6

SOURCE ASSESSMENT – SEDIMENT

Point and nonpoint sources of sediment were assessed in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources in impaired and reference watersheds including: MRLC land use/land cover data, water quality monitoring and point source data provided by VADEQ, STATSGO soils data (NRCS), site visit observations, literature sources, and other information. Procedures and assumptions used in estimating sediment sources in impaired and reference watersheds are described in the following sections. Whenever possible, data development and source characterization was accomplished using locally-derived information.

6.1 Assessment of Nonpoint Sources

Erosion of the land results in the transport of sediment to receiving waters through various processes. Factors that influence erosion include characteristics of the soil, vegetative cover, topography, and climate. Nonpoint sources, such as agricultural land uses and construction areas, are large contributors of sediment because the percentage of vegetative cover is typically lower. Urban areas can also contribute quantities of sediment to surface waters through the build-up and eventual washoff of soil particles, dust, debris, and other accumulated materials. Pervious urban areas, such as lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. In addition, streambank erosion and scouring processes can result in the transport of additional sediment loads.

6.1.1 Agricultural Land

Agricultural land was identified as a primary source of sediment in the Hunting Camp Creek watershed. Agricultural runoff can contribute increased pollutant loads when farm management practices allow soils rich in nutrients from fertilizers or animal waste to be washed into the stream, increasing instream sediment levels. The erosion potential of cropland and over-grazed pasture land is particularly high due to the lack of year-round vegetative cover. The use of cover crops and other management practices have been shown to reduce the transport of pollutant loads from agricultural lands.

The MRLC land use coverage for the Hunting Camp Creek watershed is shown in Figure 2.1.

6.1.2 Forest Land

Agricultural and urban development in this watershed has replaced some mature forest areas, especially along the stream and at lower elevations. The sediment yield from undisturbed forest lands, especially during the growing season, is low due to the amount of dense vegetative cover, which stabilizes soils and reduces rainfall impact.

6.1.3 Urban Areas

Urban land uses represented in the MRLC land use coverage for the Hunting Camp Creek watershed include commercial, transportation, and residential areas. Urban land uses consist of pervious and impervious areas. Stormwater runoff from impervious areas, such as paved roads and parking lots, contribute pollutants that accumulate on these surfaces directly to receiving waters without being filtered by soil or vegetation. Sediment deposits in impervious areas originate from vehicle exhaust, industrial and commercial activities, outdoor storage piles, and other sources. In addition, stormwater runoff can cause streambank erosion and bottom scouring through high flow volumes, resulting in increased sedimentation and other habitat impacts.

The primary urban sources of sediment are construction sites and other pervious lands. Construction sites have high erosion rates due to the removal of vegetation and top soil. Typical erosion rates for construction sites are 35 to 45 tons per acre per year as compared to 1 to 10 tons per acre per year for cropland. Residential lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses.

Urban land use areas were separated into pervious and impervious fractions based on the estimated percent impervious surface of each urban land use category. Field observations and literature values were used to determine the effective percent imperviousness of urban land uses (Table 6.1).

Table 6.1 Percent imperviousness of urban land uses

Urban land uses	Percent impervious
Low Intensity Residential	10%
High Intensity Commercial/Industrial/Transportation	50%

6.1.4 Streambank Erosion

Streambank erosion can be a significant source of sediment to the stream. The removal of riparian vegetation that provides bank stability is the primary cause of streambank erosion. Agricultural development and stormwater discharges are responsible for identified bank erosion areas along Hunting Camp Creek. Stream channelization, livestock grazing, and other factors contribute to the instability of stream banks leading to scouring during storm periods.

6.2 Assessment of Point Sources

Point sources can contribute sediment loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ. There are currently no point sources in the watershed that discharge to streams in the Hunting Camp Creek watershed. The Bastian WWTP is located in the watershed, but discharges to Wolf Creek downstream, therefore, this point source does not contribute sediment to Hunting Camp Creek.

SECTION 7

WATERSHED MODELING – SEDIMENT

7.1 Reference Watershed Approach

7.1.1 Background

Biological communities respond to any number of environmental stressors, including physical impacts and changes in water and sediment chemistry. According to the 2002 303(d) Fact Sheet for Hunting Camp Creek, erosion and sedimentation were identified as the likely causes of the benthic impairment.

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Virginia does not currently have numeric criteria for nutrients (i.e., total phosphorus and total nitrogen), sediment, and other parameters that may be contributing to the impaired condition of the benthic community in this stream. A reference watershed approach was, therefore, used to determine the primary benthic community stressors and to establish numeric endpoints for these stressors. This approach is based on selecting non-impaired watersheds that share similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. The Virginia Stream Condition Index (VaSCI) was used to define differences in the benthic communities in impaired and reference streams (USEPA 2003). Loading rates for pollutants of concern are determined for impaired and reference watersheds through modeling studies. Both point and nonpoint sources are considered in the analysis of pollutant sources and in watershed modeling. Numeric endpoints are based on reference watershed loadings for pollutants of concern and load reductions necessary to meet these endpoints are determined. TMDL load allocation scenarios are then developed based on an analysis of the degree to which contributing sources can be reasonably reduced

7.1.2 Reference Watershed Selection

The reference watershed selection process is based on a comparison of key watershed, stream and biological characteristics. The goal of the process is to select one or several similar, unimpaired reference watersheds that can be used to identify benthic community stressors and develop TMDL endpoints. Reference watershed selection was based on the results of VADEQ biomonitoring studies and comparisons of key watershed characteristics. Data used in the reference watershed selection process for the Hunting Camp Creek watershed are shown in Table 7.1.

Table 7.1 Reference watershed selection data

Biomonitoring Data	Ecoregion Coverages
Topography	Land use Distribution
Soils	Watershed Size
Water Quality Data	Point Source Inventory

7.1.3 Selected Reference Watershed

The Laurel Creek watershed, delineated at the mouth, was selected as the reference for this TMDL study. Laurel Creek is a non-impaired tributary to Hunting Camp Creek. The determination to select this as the reference watershed was based on the degree of similarity between Laurel Creek and its associated watershed to the impaired stream and the results of the VaSCI scores. USFS biomonitoring data also confirmed the Laurel Creek has a healthy benthic macroinvertebrate community. Figures 7.2 and 7.3 show comparisons of the MRLC land use and soils distributions within the Hunting Camp Creek and Laurel Creek watersheds.

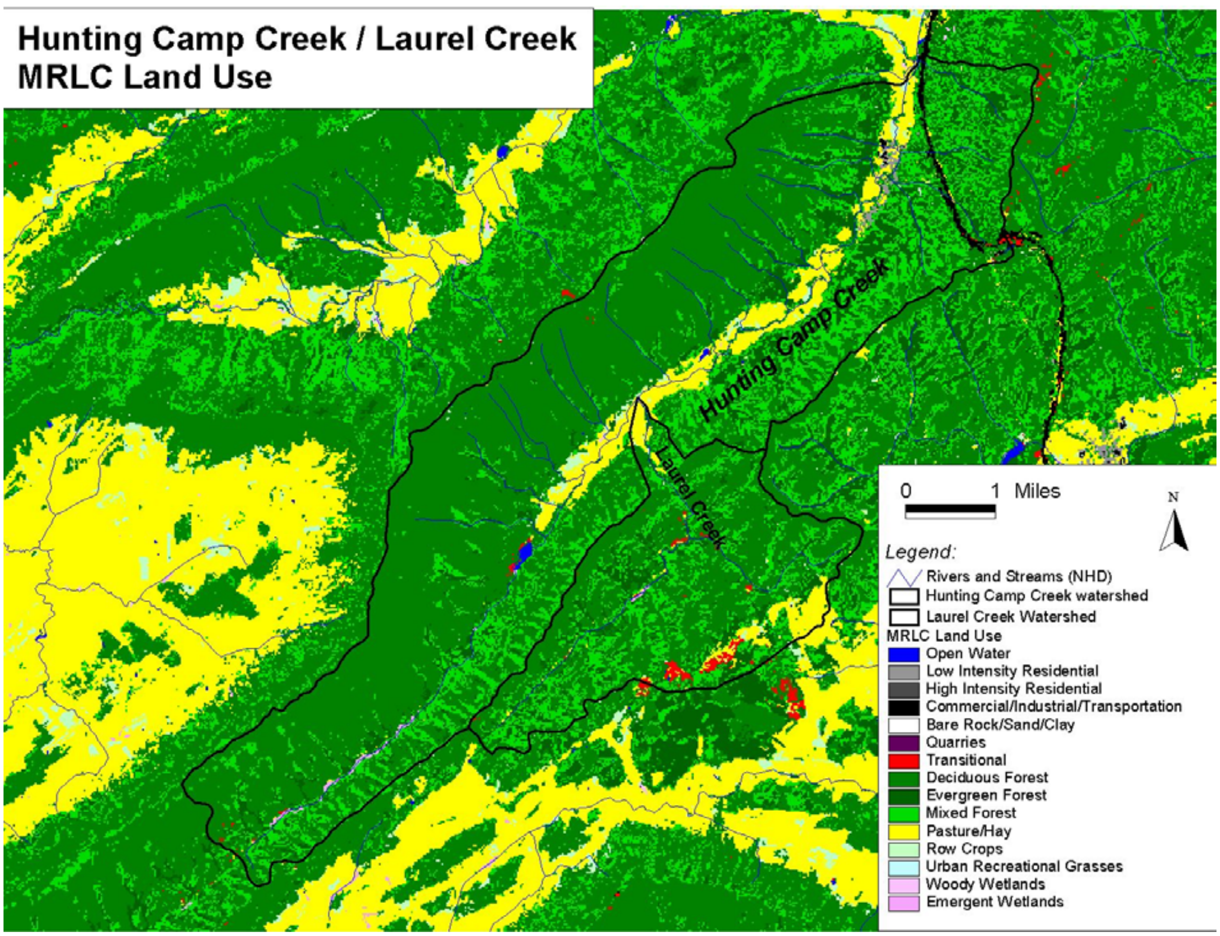

Figure 7.1 Land use comparison - Hunting Camp Creek and Laurel Creek watersheds

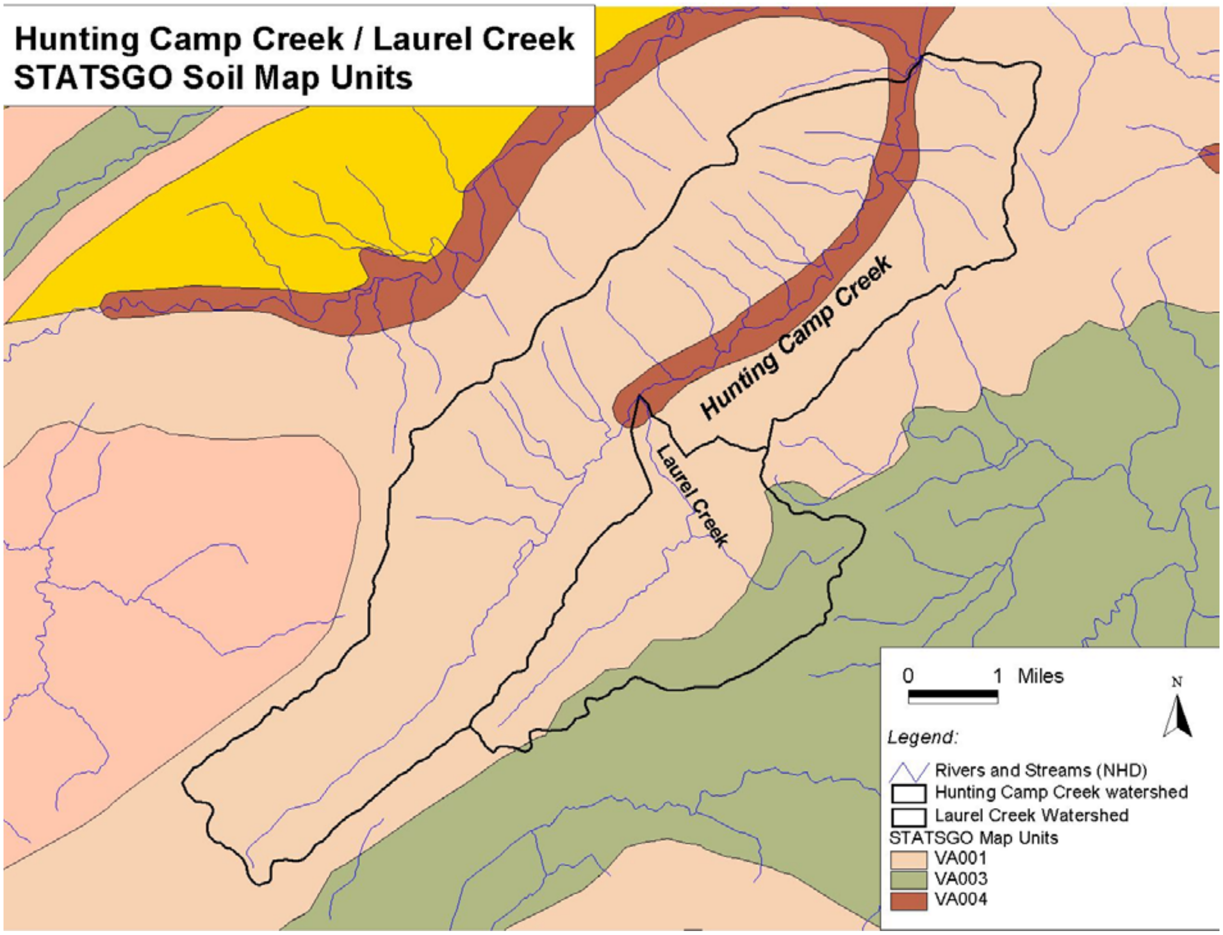

Figure 7.2 Soils comparison - Hunting Camp Creek and Laurel Creek watersheds

7.2 Watershed Model

TMDLs were developed using BasinSim 1.0 and the GWLF model (Dai et al. 2000). An empirical streambank erosion algorithm, developed by Pennsylvania State University researchers, was also incorporated into the modeling framework in order to represent this sedimentation source (discussed in Section 7.4). The GWLF model, which was originally developed by Cornell University (Haith and Shoemaker 1987, Haith et al. 1992), provides the ability to simulate runoff, sediment, and nutrient loadings from watersheds given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. Point source discharges also can contribute to loads to the stream. Evapotranspiration is determined using daily weather data and a cover factor dependent on land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be found in the original GWLF paper (Haith and Shoemaker 1987) and GWLF User's Manual (Haith et al. 1992). In addition, several improvements were made to the GWLF model, including the representation of sediment accumulation and washoff from impervious urban areas in the watershed. The inclusion of these loads is based on empirical sediment accumulation and washoff functions.

For execution, the model requires three separate input files containing transport, nutrient, and weather-related data. The transport file (TRANSPRT.DAT) defines the necessary parameters for each source area to be considered (e.g., area size, curve number) as well as global parameters (e.g., initial storage, sediment delivery ratio) that apply to all source areas. The nutrient file (NUTRIENT.DAT) specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations). The nutrient file is necessary for the model to run but is not used in any of the calculations. The weather file (WEATHER .DAT) contains daily average temperature and total precipitation values for each year simulated.

7.3 Model Setup

Watershed data needed to run the GWLF model in BasinSim 1.0 were generated using GIS spatial coverages, water quality monitoring and streamflow data, local weather data, literature values, and other information. The Hunting Camp Creek watershed and reference watershed were delineated based on hydrologic and topographic data (USGS 7.5 minute digital topographic maps (24K DRG - Digital Raster Graphics)), and the location of DEQ monitoring stations. The outlet of the Hunting Camp Creek watershed is the downstream limit of the impaired segment, which is also the mouth of the stream. The reference watershed outlet is located at the mouth of Laurel Creek. To equate target and reference watershed areas for TMDL development, the total area for the reference watershed was increased to be equal to the area of the Hunting Camp Creek watershed, after hydrology calibration. To accomplish this, land use areas (in the reference watershed) were proportionally increased based on the percent land use distribution.

Local rainfall and temperature data were used to simulate flow conditions in modeled watersheds. Daily precipitation and temperature data were obtained from local National Climatic Data Center (NCDC) weather stations. The weather stations and data periods that correspond with the modeled watersheds are shown in Table 7.2. The period of record selected for model calibration runs (April 1, 1990 through September 30, 2000 for the impaired and reference models) was based on the availability of recent weather data and corresponding streamflow records. The weather file used in watershed simulation for both the impaired and reference watersheds was constructed using precipitation data collected at the NCDC station at Staffordsville and temperature data collected at the NCDC station at Bristol Airport.

Table 7.2 Weather stations used in GWLF models

Watershed	Weather Station	Data Type	Data Period
Hunting Camp Creek Laurel Creek	Staffordsville (VA8022)	Daily Precipitation	4/1/90 - 12/31/00
	Bristol Airport (TN1094)	Daily Temperature	4/1/90 - 12/31/00

Daily streamflow data are needed to calibrate watershed hydrologic parameters in the GWLF model. The USGS gage station located on Wolf Creek near Narrows, Virginia was used to calibrate both the Hunting Camp Creek watershed and the Laurel Creek watershed. Table 7.3 lists the USGS gaging station along with the period of record used for the watersheds.

Table 7.3 USGS gaging stations used in GWLF models

Watershed	USGS station number	USGS gage location	Data Period
Hunting Camp Creek Laurel Creek	03175500	Wolf Creek near Narrows, VA	4/1/90 – 12/31/00

7.4 Explanation of Important Model Parameters

In the GWLF model, the nonpoint source load calculation is affected by terrain conditions, such as the amount of agricultural land, land slope, soil erodibility, farming practices used in the area, and by background concentrations of nutrients (nitrogen and phosphorus) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized as follows:

Areal extent of different land use/cover categories: The MRLC land use coverage was used to calculate the area of each land use category in impaired and reference watersheds, respectively.

Curve number: This parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type and is calculated directly using digital land use and soils coverages. Soils data for both the impaired and reference watersheds were obtained from the State Soil Geographic (STATSGO) database for Virginia, developed by NRCS.

K factor: This factor relates to inherent soil erodibility, and it affects the amount of soil erosion taking place on a given unit of land. The K factor and other Universal Soils Loss Equation (USLE) parameters were downloaded from the NRCS Natural Resources Inventory (NRI) database (1992). Average values for specific crops/land uses in the watershed county were used (Bland County).

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices used. Values range from 0 to 1.0, with larger values indicating a higher potential for erosion.

P factor: This factor is directly related to the conservation practices used in agricultural areas. Values range from 0 to 1.0, with larger values indicating a higher potential for erosion.

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This parameter relates to the amount of water that can be stored in the soil and affects runoff and infiltration.

Other less important factors that can affect sediment loads in a watershed also are included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF User's Manual (Haith et al. 1992). Pages 15 through 41 of the manual provide specific details that describe equations and typical parameter values used in the model.

Streambank Erosion Calculation

The sediment load from streambank erosion was calculated outside the model based on an empirical equation developed by Pennsylvania State University researchers and published in the AVGWLF Users Guide (Version 4.0, November 2001). In this equation, the sediment load contributed by bank erosion is estimated by calculating a watershed-specific lateral erosion rate (LER) and then multiplying the LER by the total length of streams in the watershed, the average stream height, and the average soil bulk density. The LER = $aq^{0.6}$, where a = an empirically-derived constant related to the mass of soil eroded from the streambank depending on various watershed conditions, and q = monthly stream flow. The parameter "*a*" is dependent upon percent developed land, animal density, average curve number value, average soil "k" factor value, and mean annual precipitation in the watershed.

7.5 Hydrology Calibration

Using the input files created in the BasinSim 1.0, GWLF predicted overall water balances in impaired and reference watersheds. As discussed in Section 7.3, the modeling period is determined based on the availability of weather and flow data that were collected during the same time period. The Hunting Camp Creek watershed was calibrated for a period of ten years from 4/1990 to 3/2000 using the stream flow data from USGS gage 03175500 on Wolf Creek. The USGS gage location does not coincide with the outlet (pour point) of each modeled watershed; therefore, stream flow measurements were normalized by area to facilitate calibration. The Hunting Camp Creek watershed was calibrated and then the same hydrology parameters were used to run the Laurel Creek reference watershed model. Calibration statistics are presented in Table 7.4 and Figure 7.3. In general, an R^2 value greater than 0.7 indicates a strong, positive correlation between simulated and observed data. These results indicate a good correlation between simulated and observed results. A total flow volume error percentage of less than 7% was achieved in calibration of the model for the watersheds. In general, the seasonal trends and peaks are captured reasonably well. Note that observed flow data are missing for the period of October 1995 through September 1996. It is assumed that this is the cause of some differences between observed and modeled flows and artificially lowered the R^2 value for the hydrology calibration period. Additional differences between observed and modeled flows are likely due to inherent errors in flow estimation procedures based on normalization for watershed size and the proximity of the selected weather stations to each modeled watershed and the corresponding USGS gage.

Table 7.4 GWLF flow calibration statistics

Modeled Watershed	Simulation Period	R^2 (Correlation) Value	Total Volume % Error
Hunting Camp Creek Laurel Creek	4/1/90 - 3/31/00	0.6015	6.6%

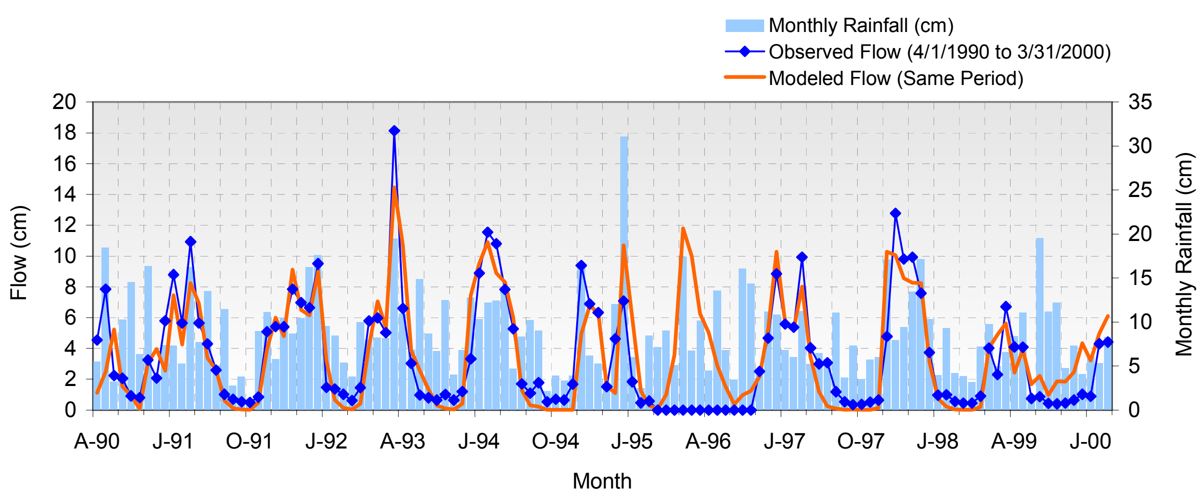

Figure 7.3 Hunting Camp Creek hydrology calibration using USGS gage 03175500

SECTION 8

TMDL METHODOLOGY - BACTERIA

8.1 TMDL Calculation

The *E. coli* bacteria TMDL established for Hunting Camp Creek consists of a point source waste load allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The TMDL is the total amount of a pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards. For *E. coli*, TMDLs are expressed in terms of bacteria counts (or resulting concentration).

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources (e.g., sewage treatment plants or municipal separate storm sewer system (MS4) permits). The LA portion represents the loading assigned to nonpoint sources (e.g., failing septic discharges, cattle direct deposition). The MOS accounts for any uncertainty in the data and the modeling process. Implicit MOS factors were incorporated into the TMDL development process through the use of conservative model assumptions and source load estimates.

8.2 Wasteload Allocations

There are no point sources that discharge to streams in the Hunting Camp Creek watershed. The Bastian WWTP is located in the watershed but discharges to Wolf Creek downstream. As a result, the WLA for Hunting Camp Creek is zero.

8.3 Load Allocations

Load allocations to nonpoint sources are divided into land-based loads from land uses in the watershed and direct discharges from straight pipes, cattle, and wildlife. Failing septic discharges were included in the built up (urban land) load.

Using the model developed to represent existing conditions, various allocation scenarios were examined for reducing *E. coli* loads to levels that would result in the attainment of water quality standards. This examination focused on understanding the water quality response and sensitivity of Hunting Camp Creek to variations in source loading characteristics.

Allocation scenarios are presented with percent violations between 1/1/1990 and 9/30/2004 in Table 8.1. Scenario 8 presents the source reductions required to achieve the *E. Coli* instantaneous and calendar month geometric mean criteria. Scenario 4 presents the reductions required to meet the Stage 1 implementation goal of <10% violation of the instantaneous criteria.

The calendar month geometric mean concentration for existing conditions and the final allocation scenario are shown in Figure 8.1. The instantaneous concentration for existing and the final allocation scenario are shown in Figure 8.2. Reductions in load contributions from in-stream sources had the greatest impact on E. coli concentrations. Significant reductions from land-based loadings were also required to meet water quality standards. Direct deposition during low flow conditions and loads transported by runoff during high flow conditions are controlled in these allocation scenarios.

Table 8.1 TMDL allocation scenarios and percent violations

Scenario Number	Direct (Instream) Sources			Indirect (NPS) Sources				Percent Violations	
	Straight Pipes	Livestock	Wildlife	Cropland	Pasture	Built up	Forest	Inst. Exceeds 235 cfu/100ml	Geom. Exceeds 126 cfu/100ml
1	0	0	0	0	0	0	0	56%	66%
2	50	50	0	50	50	50	0	36%	46%
3	100	90	0	60	60	75	0	12%	17%
4	100	91	0	79	79	79	0	10%	17%
5	100	95	0	85	85	85	0	5%	11%
6	100	99	0	99	99	99	0	0%	4%
7	100	99	20	99	99	99	0	0%	1%
8	100	99	22	99	99	99	0	0%	0%

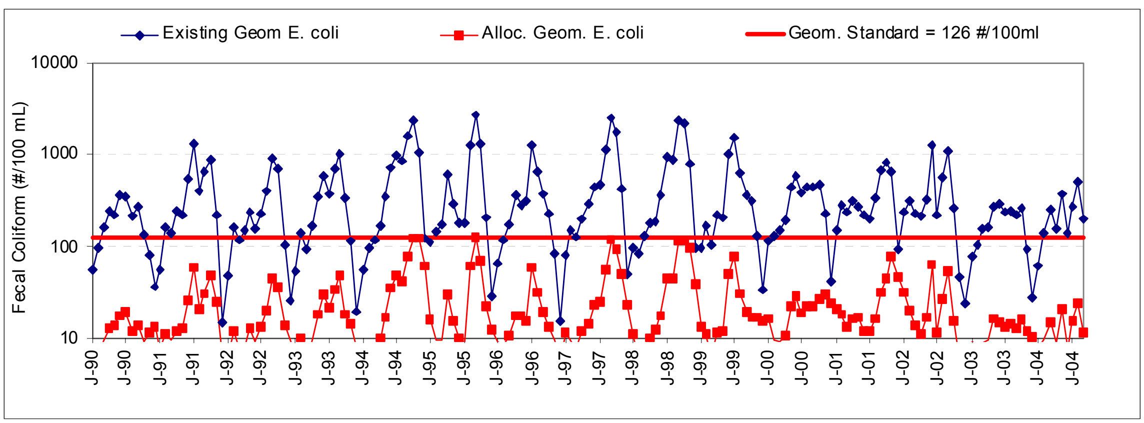

Figure 8.1 Calendar month geometric mean concentrations for existing and final allocation scenario

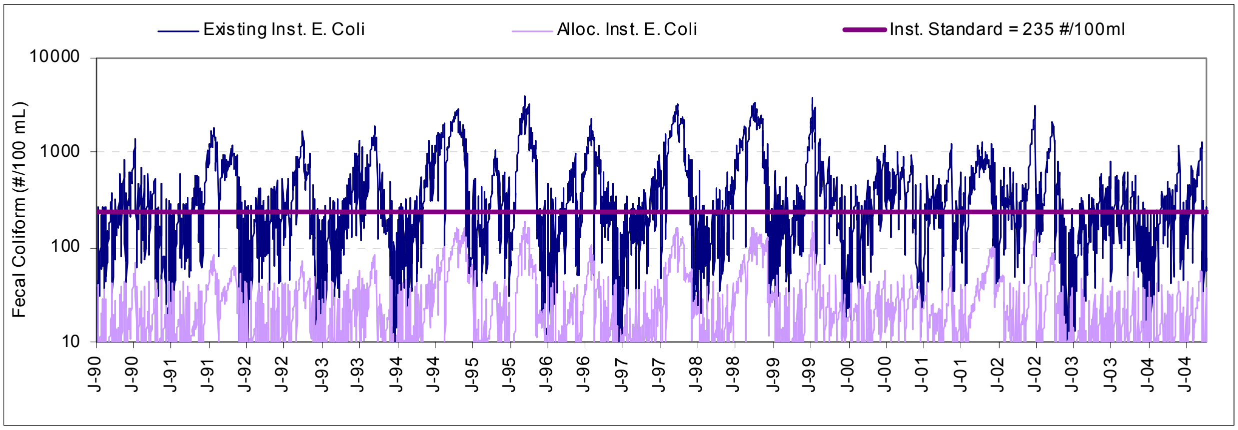

Figure 8.2 Instantaneous concentrations for existing and final allocation scenario

The Load Allocations (LAs) under Scenario 8 are presented in Table 8.2. There are no point sources that discharge to streams in the Hunting Camp Creek watershed, therefore, the WLA is zero. The load allocation in this scenario includes a 99% reduction in cropland and pasture land-based sources in the watershed, and a 99% reduction in built up (urban) land-based sources in the watershed. No reductions are required in forest land-based sources in the watershed. In addition, this load allocation scenario includes a 100% reduction in direct deposition of *E. coli* bacteria from straight pipes, and a 99% reduction in direct deposition of *E. coli* from livestock. A 22% reduction in direct deposition of *E. coli* from wildlife is also required to meet the geometric mean criteria for *E. coli*. The TMDL is presented in Table 8.3.

Table 8.2 Existing and allocation loads for LAs under allocation scenario 8

Sources		Total Annual Loading for Existing Conditions (cfu/yr)	Total Annual Loading for Allocation Conditions (cfu/yr)	Percent Reduction
Direct	Straight Pipes	<1.00E+4	<1.00E+4	100%
	Livestock	3.35E+13	3.35E+11	99%
	Wildlife	2.35E+12	1.83E+12	22%
Indirect	Cropland	1.06E+12	1.06E+10	99%
	Pasture	2.55E+13	2.55E+11	99%
	Built up	7.93E+12	7.93E+10	99%
	Forest	4.67E+12	4.67E+12	0%
Total		7.50E+13	7.18E+12	90%

Table 8.3 *E. coli* TMDL for Hunting Camp Creek

WLA	LA	MOS	TMDL
0.00E+00	7.18E+12	Implicit	7.18E+12

8.4 Consideration of Critical Conditions

The LSPC model is a continuous-simulation model; therefore, all flow conditions are taken into account for loading calculations. The modeling period represents typical high and low flow periods in the watershed; therefore, loads contributed through direct deposition (e.g., cattle in streams) and through runoff under critical conditions were accounted for in the model.

8.5 Consideration of Seasonal Variations

Seasonal variation was explicitly included in the modeling approach for this TMDL. Bacteria accumulation rates for each land use were determined on a monthly basis. The monthly accumulation rates accounted for the temporal variation in activities within the watershed, including seasonal application of agricultural waste, grazing schedules of livestock, and seasonal variation in number of cows in the stream. Also, the use of continuous simulation modeling resulted in consideration of the seasonal aspects of rainfall patterns. In addition, seasonal variation was accounted for in the allocation scenario.

SECTION 9

TMDL METHODOLOGY – SEDIMENT

9.1 TMDL Calculation

Impaired and reference watershed models were calibrated for hydrology using the same modeling period and weather input file. To establish baseline (reference watershed) loadings for sediment, the GWLF model results for the Laurel Creek watershed (reference) were used. For TMDL calculation, both the calibrated impaired and reference watersheds were run for a 10-year period from 4/1/1990 to 3/31/2000. Based on the availability of weather and flow data, it is assumed that this period sufficiently captures hydrologic and weather conditions. In addition, the total area for the reference watershed was increased to be equal to the target watershed, as discussed in Section 5.3. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The 9-year means for pollutants of concern were determined for each land use/source category in the impaired and the reference watersheds. The first year of the model run was excluded from the pollutant load summaries because the GWLF model takes a few months in the first year to stabilize. Model output for Hunting Camp Creek is only presented for the years following the initialization year, although the model was run for a 10-year time period (4/1990 - 3/2000). The existing average annual sediment loads for the Hunting Camp Creek watershed are presented in Table 9.1.

Table 9.1 Existing sediment loading in the Hunting Camp Creek watershed

Source Category	Sediment Load (lbs/yr)	Sediment % of Total
Transitional	160,320	6.86%
Open Water	0	0.00%
Woody Wetlands	0	0.00%
Emergent Herbaceous Wetlands	0	0.00%
Pasture/Hay	768,007	32.84%
Row Crops	339,402	14.51%
Deciduous Forest	121,174	5.18%
Evergreen Forest	14,005	0.60%
Mixed Forest	28,506	1.22%
Urban (pervious & impervious)	1,025	0.04%
Groundwater	0	0.00%
Point Source	0	0.00%
Streambank Erosion	905,874	38.74%
Total	2,338,313	100.00%

The TMDLs established for Hunting Camp Creek consist of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). There are no existing point sources in the watershed, so the WLA is equal to zero. The sediment TMDL for the Hunting Camp Creek watershed was based on the total load calculated for the Laurel Creek reference watershed (area adjusted to the impaired watershed size).

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources (none in this case). The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of 10% was used in TMDL calculations to provide an additional level of protection for designated uses.

The TMDL for Hunting Camp Creek was calculated by adding reference watershed loads for sediment together to give the TMDL value (Table 9.2).

Table 9.2 Sediment TMDL for the Hunting Camp Creek watershed

TMDL (lbs/yr)	WLA (lbs/yr)	LA (lbs/yr)	MOS (lbs/yr)	Overall Percent Reduction
1,580,324	0	1,422,193	158,132	39%

9.2 Wasteload Allocation

There are no point source facilities that discharge to streams in the watershed, therefore, the WLA is zero.

9.3 Load Allocation

Load allocations were assigned to each source category in the watershed. Several allocation scenarios were developed for the Hunting Camp Creek watershed to examine the outcome of various load reduction combinations. The recommended scenario for Hunting Camp Creek (Table 9.3) is based on maintaining the existing percent load contribution from each source category. The recommended scenario balances the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. Loadings from certain source categories were allocated according to their existing loads. For instance, sediment loads from forest lands represent the natural condition that would be expected to exist; therefore, the loading from forest lands was not reduced.

Table 9.3 Recommended sediment allocations for the Hunting Camp Creek watershed

Source Category	Sediment Load Allocation (lbs/yr)	Sediment % Reduction by Source
Transitional	89,779	44%
Open Water	0	0%
Woody Wetlands	0	0%
Emergent Herbaceous Wetlands	0	0%
Pasture/Hay	445,444	42%
Row Crops	196,853	42%

Source Category	Sediment Load Allocation (lbs/yr)	Sediment % Reduction by Source
Deciduous Forest	121,174	0%
Evergreen Forest	14,005	0%
Mixed Forest	28,506	0%
Urban (pervious & impervious)	1,025	0%
Groundwater	0	0%
Point Source	0	0%
Streambank Erosion	525,407	42%
Total	1,422,193	39%

9.4 Consideration of Critical Conditions

The GWLF model is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is usually a significant lag time between the introduction of sediment to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective of the waterbody.

9.5 Consideration of Seasonal Variations

The continuous-simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season and hours of daylight for each month. The combination of these model features accounts for seasonal variability.

SECTION 10

REASONABLE ASSURANCE AND IMPLEMENTATION

10.1 TMDL Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic and bacteria impairments on Hunting Camp Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

10.2 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers. This practice should also reduce streambank erosion and sedimentation by promoting riparian vegetation growth and bank stabilization.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems. Connections to the new Bastian WWTP have reduced bacteria concentrations from failing septic systems in the watershed. Increases in the number of houses connected to the sewage collection system in the future will provide additional benefits to the stream.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plans. While specific goals for BMP implementation will be established as part of the implementation plan development, for the bacteria TMDL the following Stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

10.3 Stage 1 Scenario

The goal of the stage 1 scenario is to reduce the bacteria loadings from controllable sources, such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenario was generated with the same model setup as was used for the TMDL allocation scenarios. This scenario is presented with the other allocation scenarios in Section 8.

10.4 Reasonable Assurance for Implementation

10.4.1 Follow-Up Monitoring

VADEQ will continue monitoring water quality and the benthic community in Hunting Camp Creek in accordance with its ambient monitoring and biomonitoring programs to evaluate reductions in bacteria counts, habitat improvements through sediment reductions, and the effectiveness of TMDL implementation in attainment of water quality standards.

10.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plans, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plans into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

10.4.3 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

10.4.4 Proposed Water Quality Standards Revisions

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria will become effective pending EPA approval and can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.state.va.us/wqs/WQS03AUG.pdf.

Based on the above, EPA and Virginia have developed the following TMDL implementation process. First in this process is the development of a Stage 1 scenario as discussed above. The pollutant reductions in the Stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL. During the implementation of the Stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 10.1 above. DEQ will re-assess water and biological quality in the stream during and subsequent to the implementation of the Stage 1 scenario to determine if water quality standards are attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels and other problems due to uncontrollable sources.

SECTION 11

PUBLIC PARTICIPATION

A stakeholder and TMDL study kickoff meeting was held on June 25, 2003 at the Bland County School Board Offices in Bastian, Virginia. There were 8 people in attendance at the meeting, including 1 from VADEQ and 1 from Tetra Tech. A watershed site visit was also conducted on this date. Important information regarding likely stressors and sources was discussed with state environmental personnel and local stakeholders.

The first public meeting on the development of TMDLs for the Hunting Camp Creek watershed was held on September 22, 2003 at the Bland County School Board Offices in Bastian, Virginia. There were 26 people in attendance, including 2 from VADEQ, 1 from VADCR, and 1 from Tetra Tech. Copies of the presentation materials were made available for public distribution at the meeting. Stakeholder comments were provided regarding agricultural data and other key information. This valuable information was used to better represent pollutant sources and watershed conditions in modeling and TMDL development efforts. No written comments were received.

The second and final public meeting on the development of TMDLs for the Hunting Camp Creek watershed was held on November 8, 2004 at the Bland County School Board Offices in Bastian, Virginia. There were 42 people present at the meeting, including 1 from VADEQ, 1 from VADCR, 2 from Tetra Tech, and at least 2 from the Big Walker Soil and Water Conservation District. Copies of the Draft TMDL report and presentation materials were made available for public distribution at the meeting. No written comments were received.

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GLOSSARY

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)

Ambient water quality. Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.

Aquatic ecosystem. Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.

Background levels. Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.

Bacteria. Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.

Bacterial decomposition. Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Basin. A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.

BasinSim 1.0. GWLF based modeling interface developed by Dai et al. 2000.

Benthic. Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.

Benthic organisms. Organisms living in, or on, bottom substrates in aquatic ecosystems.

Best management practices (BMPs). Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Calibration. The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Clean Water Act (CWA). The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.

Concentration. Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).

Confluence. The point at which a river and its tributary flow together.

Contamination. The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.

Conventional pollutants. As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.

Cost-share program. A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).

Critical condition. The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.

Decay. The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.

Decomposition. Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds.

Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

Discharge. Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.

Discharge Monitoring Report (DMR). Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.

Discharge permit (see VPDES). A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System (NPDES), under provisions of the Federal Clean Water Act.

Diurnal. Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours.

Domestic wastewater. Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.

Dynamic model. A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.

Ecosystem. An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.

Effluent. Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.

Empirical model. Use of statistical techniques to discern patterns or relationships underlying observed or measured data for large sample sets. Does not account for physical dynamics of waterbodies.

Endpoint. An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Existing use. Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).

E. coli. Escherichia coli is a bacterium that is commonly found in the digestive tract of warm blooded animals. Various strains can cause gastrointestinal illness and other infections.

Enterococci. A subgroup of fecal streptococci bacteria that can cause gastroenteritis.

Failing Septic System. Typically an older or improperly maintained septic systems that discharges waste to the soil surface where it is available for washoff into surface waters.

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth.

Ground water. The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.

GWLF. Generalized Watershed Loading Functions. Empirical watershed loading model developed by Cornell University (Haith and Shoemaker 1987; Haith et al. 1992)

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrologic cycle. The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.

Hydrology. The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Indicator organism. An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.

KLSCP. A composite factor used to measure soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P).

Loading, Load, Loading rate. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.

Load allocation (LA). The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).

Loading capacity. The greatest amount of loading a water can receive without violating water quality standards.

LSPC. Loading Simulation Program C++

Margin of safety (MOS). A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

Metrics. Measurements of the benthic community which are used to assess biological condition.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.

Monitoring. Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

MRLC. Multi Resolution Land Characteristics. Land use coverage developed by USEPA and USGS.

MS4. Multiple Separate Storm Sewer System

MUID. Soil map unit in the STATSGO database developed by NRCS. A map unit is composed of several soil series that have similar properties.

Narrative criteria. Nonquantitative guidelines that describe the desired water quality goals.

National Pollutant Discharge Elimination System (NPDES). The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.

Natural waters. Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.

NCDC. National Climatic Data Center

NHD. National Hydrography Dataset (developed by USGS)

Nonpoint source. Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

NRCS. Natural Resource Conservation Service.

Numeric targets. A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.

Organic matter. The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.

Permit. An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

Phased Implementation. Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.

Point source. Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollutant. Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Public comment period. The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

Rapid Bioassessment Protocol (RBP). Various methods that are used to assess the biological condition of waterbodies.

Receiving waters. Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

Reference watershed. A non-impaired watershed with similar characteristics that is used to define the baseline, reference, or natural condition.

Residence time. Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.

Restoration. Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.

Riparian areas. Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.

Riparian zone. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.

Runoff. That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Sewer. A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.

Simulation. The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Slope. The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

STATSGO. State Soil Geographic database developed by NRCS

Straight Pipe. Illicit and untreated discharge of waste typically from a private home.

Stream restoration. Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.

Stressor Identification. Refers to the identification of stressors causing biological impairment in aquatic ecosystems. Methodology was developed by USEPA and Tetra Tech, Inc.

Surface water. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.

Taxa. A taxonomic group of any rank, including all the subordinate groups. Any group of organisms, populations, or taxa considered to be sufficiently distinct from other such groups to be treated as a separate unit.

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Topography. The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.

Total Maximum Daily Load (TMDL). The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Tributary. A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.

Total Suspended Solids (TSS). A measure of the amount of suspended material in the water column.

USEPA. United States Environmental Protection Agency

USGS. United States Geological Survey

USLE. Universal Soil Loss Equation. Equations used to calculate soil loss/erosion.

Validation. Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

Virginia Stream Condition Index (VaSCI). Bioassessment index that provides a detailed assessment of the benthic macroinvertebrate community in Virginia’s wadeable, non-coastal streams. Developed by USEPA, VADEQ, and Tetra Tech, Inc (2003).

VDH. Virginia Department of Health.

VDGIF. Virginia Department of Game and Inland Fisheries.

Virginia Pollutant Discharge Elimination System (VPDES). The Virginia state program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.

Wasteload allocation (WLA). The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).

Wastewater. Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.

Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.

Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

Water quality criteria. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water quality standard. Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

Watershed. A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

WQIA. Water Quality Improvement Act.